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A PRACTICAL TREATISE

UPON

STEAM HEATING

A PRACTICAL TREATISE
UPON
STEAM HEATING

EMBRACING METHODS AND APPLIANCES FOR

WARMING BUILDINGS,
HEATING WATER AND COOKING BY STEAM

LOW PRESSURE, HIGH PRESSURE
AND EXHAUST STEAM

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PREFACE.

THE practice of steam heating is gradually growing in favour, but hitherto the number of engineers who profess the work in this country, and are skilled at it, has been comparatively small. There can be no doubt that this has been due, in a large measure, to the want of an English book upon the subject, none having been written, so far as the writer of this, by the fullest inquiry, can ascertain. The want of a book and the readily acquired knowledge that a book gives, naturally tend to retard progress; for if a man is wanting in skill in this work he may, even unconsciously, speak more highly of some other mode of heating with which he is familiar.

There is considerable certainty that steam will never be preferred to hot water for general heating work—not in residences for instance—but for many purposes it excels hot water and every other means of affording warmth. On this account it is likely to grow in favour and make a practical treatise useful and sought for.

As purposes for which steam is specially suited may be mentioned factories, institutions, some hotels, very high buildings (in which the water pressure would be great), also Board schools, public halls and places of entertainment, and, lastly, churches and places of worship generally. It is doubtful whether a church exists which is heated by steam, yet this agent is eminently suited. A steam heating plant, properly constructed, is frost-proof, for the pipes and radiators are empty when cold. Steam heat is the quickest in results, for steam can be quickly generated and then the pipes and parts are heated to their maximum heat at once. In places not used every day, or places where heat is not kept up all night during cold weather, quick results in warmth after lighting the fire in the morning are much appreciated.

A steam heating apparatus is cheaper to erect than one for hot water, which is an advantage if steam heat serves the purpose equally well. Nothing, however, can be claimed in the way of special economy in fuel consumption. It rests with the engineer to choose a boiler that absorbs the heat units to best advantage. Boilers differ in this quality very much, but given a boiler for steam and one for hot water of the same size and design, and the results for a given fuel consumption would be equal for the heat units distributed. Where a difference would exist is in the first and last hours of the time of heating. With steam the heat is quickly got when the fire is lighted, and quickly lost when the fire is allowed to go out. With hot water the heat is slowly got, but it is slow to cool, even yielding warmth some time after the fire is out. If the quickness or slowness is a gain for the purpose in view, then one apparatus will be more economical in the aggregate than the other.

As these features have been mentioned, it is as well to state that steam heat has a disadvantage in being difficult of regulation. Stop-cocks cannot be used for the nice degree of regulation that is possible with hot-water: they have to be full open or shut. Again, a steam apparatus is more likely to be noisy than any other, but only in cases of poor workmanship. Noise is not a weakness of the steam, but of the designer or fitter; or it may be due to some very unfavourable conditions. In any case it rests with the engineer to make a noiseless apparatus.

It is believed the following pages embrace all the "gravity systems" of apparatus used, the one-pipe, two-pipe (wet and dry return) and the overhead, with all their details, normal or otherwise. Then follow the non-gravity works, in which the condense water cannot return directly to the boiler, the use of live high-pressure steam, also of exhaust steam from engines. It is hoped that the latter will be found particularly useful, as it enables factories, works and their offices, to be heated for next to nothing, with no attention at the source of heat. It is work having a large field of usefulness, but not cultivated to the extent it might be. Space and full description is also devoted to the comparatively new "vacuum" systems of heating by exhaust steam, which when possible of adoption, have great advantages and practical merit.

In dealing with boilers there is yet much to be said and done to obtain effectiveness. Makers' catalogues show such a peculiar confusion of heating values, and it is apparently still the practice to calculate direct (or any other) surface as having a certain fixed value whatever its position and its relation to the fire. Another fact recently noticed is, that when boilers of certain patterns are made for both hot water or steam, the working values for both purposes do not bear any fixed ratio. This, however, is now decided once for all it is hoped.

There is no cause for complaint in the variety of fittings offered to the steam heating engineer, and they have reached a high degree of perfection. The automatic regulator is deserving of special mention, as it has made steam heating possible in an enormous number of instances where it was impossible before. It is an automatic attendant almost, for it is only necessary to put fuel in the furnace and the regulator will control the draught by which combustion and steam generation and pressure are controlled in turn.

In heating water by steam, there is much that is interesting, ingenious and new. The tap which yields water at any desired temperature from cold to boiling, and this by merely connecting a cold water and a steam service to it, has certainly a great demand in store for it. The various ordinary methods of heating water by steam are brought to some degree of order for calculating quantities, and this applies to both free steam heating and affording the heat by " heaters." Perhaps the newest method is that of heating a hot water heating plant, of any magnitude, by merely attaching an injector with its necessary steam service. Some excellent results have been obtained with this.

Absolutely no data could be found on cooking by steam, and the chapter upon this subject is somewhat short. This shortness is, however, partly due to the subject of cooking utensils being omitted, it being thought that instruction for the engineer might end with the service to the utensil. The chapter embraces all methods of getting steam for cooking, from the small side-boiler of a kitchen range capable of working one pot to the independent boiler needed in a hotel.

Briefly, the aim of this treatise is to afford the working steam-heating engineer all the information there is to be had relating to the work he is engaged in, whatever branch it is, and to give this in a manner that will enable him to plan and execute work correctly, remembering that it is seldom that two apparatus ever resemble one another in detail. The designing or scheming of the work, the needed calculations for pipes and radiating surfaces, the choice of appliances, and the final execution are all described, and illustrated, with a view to making the whole as clear and as readily understood as lies within the writer's power.

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HEATING BY STEAM.

CHAPTER I.

THE PRINCIPLES OF STEAM HEATING.

THE idea and purpose of a steam heating apparatus is to afford warmth at different places, more or less scattered and remote, from one source of heat—a boiler—the same as with a hot water apparatus. The appliances used for these two distinct methods of heating—steam and hot water—are also very similar, consisting of a boiler, distributing pipes and radiators or radiating surfaces ; but except for this similarity in appliances the comparison will bear no other practical application. The principles involved, also the various phenomena, good and bad, to be considered, are so different that it is highly desirable that they be dissociated to avoid almost certain confusion.

This is particularly so with those already experienced in hot water works, but having no practical knowledge in steam heating; and in the study of this latter subject, hot water practices should not be considered to have any relationship whatever. This is pointed out because there is an impression current with many people, that some similarity does exist, and that an engineer professing one possesses the foundation of the other. The only extent to which this is correct, in fact, is in the likeness of the appliances, and the necessary knowledge of how heat is absorbed, radiated, or otherwise diffused.

Any method of heating by steam, to whatever purpose it is put, is accompanied by the condensation of steam into water when it passes into or through any vessel or space colder than itself. By the contact of steam, the vessels (pipes or radiators) are kept at a high temperature, for new steam instantly takes the place of that condensed ; and in addition to the work that the sensible heat of steam does there is the greater effect of the latent heat given out by the steam at the moment of condensation. Another important feature on which this method of heating relies is the vastly greater space steam will occupy and actively affect than could the small quantity of water that produces it. If it were not for this, great trouble would be experienced, or at least some careful provision would be necessary, for on firing up, the water line in the boiler would be seriously lowered, to the injury of the boiler. And if this loss was made good, then on the entire cooling of the apparatus the boiler would be flooded, filling the steam chamber and showing no water line at all. This, however, does not occur in a boiler of proper proportions (though it is possible to some extent with a badly designed boiler), and as a rule, the water line does not fall more than about half to three-fourths of an inch in driving out the air, and charging the system of pipes with steam.

The difference in the volumes of water and steam is as 1 to 1640, at atmospheric pressure, that is, a cubic foot of water when converted into steam becomes 1640 cubic feet of this elastic fluid. In addition to this enormous change in volume, there also occurs a peculiar phenomenon in regard to its capacity for heat. To heat water from zero to boiling point, 212° F., requires a certain known amount of heat, so many thermal units as it is expressed, but to convert that quantity of water, after it has attained boiling temperature, into steam requires four-and-a-half times as much heat. The steam will not, however, have an increased sensible temperature over the water, although it may be clearly described as water at 212° F. *plus* the heat of vaporisation. This extra heat is latent (hidden), and is known as the latent heat of steam.

The word "latent" as applied to heat does not by any means imply that the heat is lost. On subjecting steam to a cooling influence, which brings about condensation, the hidden heat manifests itself and does active service in steam heating works, yielding an amount of warmth equal to that which it took when the water became steam. It has been accurately computed that to convert a given weight of water at 212° into steam at 212°, requires an amount of heat sufficient to raise an equal weight of water through 966° F. Any given weight of water existing as steam at 212°, therefore, contains as much latent heat as would raise five times its own weight of water from freezing to boiling temperature. Were it possible to serve steam cold, it would, on condensation, give out a very high temperature due to the latent heat which would be liberated at that moment.

Although it is quite the recognised thing to speak of the perceptible or sensible steam temperature as that at which water boils in an open vessel (at sea level), viz. 212° F., yet in ordinary steam heating works the steam is generated under pressure, and this pressure causes the heat of the water and steam to be higher than that just given. In the Appendix at the end of the volume will be found a table of "Temperatures for Pressures" for steam and water, where it will be seen that a pressure of only 4 lbs. above ordinary atmospheric pressure is accompanied by a temperature of 224° F.; at 6 lbs. 230°, and so on.

This increase in temperature at which water boils is due to the fact that the ebullition that occurs does not take place at one fixed heat, whatever the conditions may be, but varies in an exact and regular way with the pressure exerted upon the water. In an open vessel, when the boiling is accompanied by a temperature of 212° we may know that the water is subjected to the atmospheric pressure that is felt at sea level, viz. 14·7 lbs. per square inch.* At elevations above sea level, on mountains for instance, the pressure of the atmosphere is less, and the maximum heat of water boiled in an open vessel is less than 212°. Roughly speaking, the boiling point of water decreases 1° F. at every 600 feet above the sea level. At some elevations boiled food is an impossibility, as water cannot be raised to a sufficient heat in the ordinary way.

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* This is with a mean barometric pressure of 30 inches. Any variation in the density or humidity of the air varies the pressure it exerts, though not very much.

On the other hand, by boiling water a good distance below sea level, in a deep mine for instance, we get a perceptible increase in temperature before ebullition occurs, and by subjecting water to still greater pressures, artificially, we can raise the boiling point very greatly, as the table in the Appendix shows.

The conservation of heat is a subject of greater importance in steam works than in any other mode of heating; not that it is commendable to lose heat at any time or by any means, but because steam cannot be lowered in temperature even a little without becoming immediately and completely lost, so to speak. With hot air or hot water a waste of heat is a clear loss of fuel, but it may have no very noticeable effect on the aggregate warmth. The heating medium may lose say five or even ten degrees of heat in passing from the boiler to the actual work and yet give excellent results, but with steam the loss may mean condensation and a disappearance. Added to this, the resulting water may give trouble, for condense water never, in any case, serves a good purpose in the steam mains.

On this account every care should be bestowed upon the steam mains and services to prevent heat radiation, or abstraction of heat by contact with cold air or other means. This is effected by enveloping the pipes with some poor heat conducting material, and this to be properly effective should be well done and in a sufficient thickness. The customary way of judging this is by the application of the hand to the covering when it is known that the pipe encased is of a full temperature. If it feels normally cool, there cannot be much loss of heat, though some authorities have it that reliance should only be placed on the condensation test. This latter, however, is too intricate for ordinary heating engineers, and in practice the results of the hand test are found sufficiently accurate to make the condensation test unnecessary.

There is another phenomenon connected with steam services, which, although it transpires in other modes of heating, does not act in such a troublesome way. This is the linear expansion of the pipes by heat. Pipes expand, of course, whenever they are heated, whatever the source of heat may be, and the expansion always occurs in diameter as well as length. The increase in diameter is so trifling as to need scarcely a thought in these works, but the increase in length is considerable, occurs very rapidly, and may strain the pipes out of alignment. In hot water and hot air works, the pipes or tubes undergo an increase in length, but it is such a slow process that everything seems to give to it, making special provision for its occurrence seldom necessary. In very long direct hot-water mains, room for expansion as well as expansion joints are provided ; but with steam services the expansion difficulty has to be thought of with nearly every service that is run. Moderately long mains or branches are seldom run direct from starting point to end. There is a spring necessary somewhere, to give to the push of the tube as it expands, otherwise irregularities must transpire. For instance, supposing a vertical service be carried from a main to one or two radiators above, as in Fig. 1. Upon expansion of the horizontal main occurring, it would probably carry the vertical connection a little to the right or left if there was room, otherwise it might break the joint. Worse than this, however, when the vertical service expanded it would either break the radiator connections, or tip the radiators up, or thrust the main down out of level,

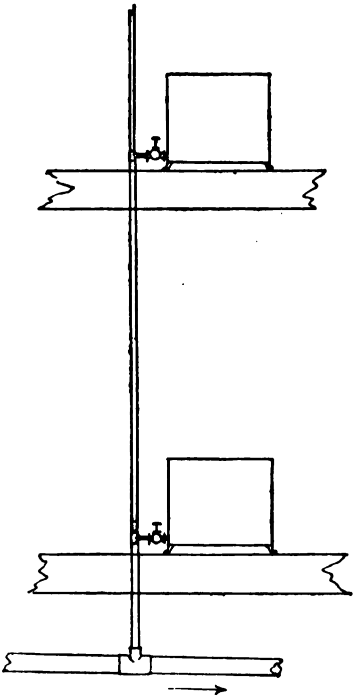

FIG. 1.

as Fig. 2. This latter would make a resting place for condense water just where the steam is required to pass most freely, and the resulting noise would be something like light artillery practice.

The radiator connections have also to be made with regard to expansion occurring as do all parts of the apparatus; but to clear up the difficulty that Fig. 2 suggests, it can be explained that a spring or swing connection, as in Fig. 3, obviates the trouble very perfectly, as it gives to the downward thrust of the vertical pipe and swings to the lateral movement of the main. This will of course be spoken of more fully when explaining an apparatus in detail.

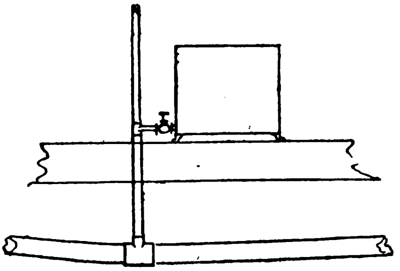

Fig. 2.

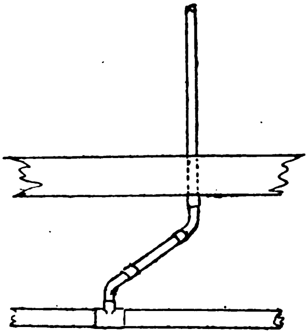

Fig. 3.

In erecting a steam heating apparatus, there are two important features that have to be jointly considered, for any neglect or even oversight with them entails a deal of trouble. These are (1) the proper disposal of the condense water, and (2) the successful expulsion of air. Condense water may be called a necessary evil. It has to occur and cannot be prevented, so provision is made to rob it of what annoying qualities it has. This is chiefly insured by arranging the pipes so that at the earliest possible moment the water may pursue a gradually descending path all the way to the boiler, without check or hindrance anywhere. Above all it must have no collecting points other than what may be specially provided, as will be described. The free and regular draining away of condense water to whatever destination is intended, is greatly aided (or at least it is not retarded) by causing the water to flow in a direction identical with the steam. Some systems are very perfect in this respect, as will be seen, but others are so devised that the steam and water at some points pass through one pipe in contrary directions. These systems are described, and they will be found to act well if care be taken in proportioning the pipes, using sizes that will accommodate both steam and water, allowing them to pass one another without conflict. These are the cheapest systems, being generally those known as "one-pipe." The "two-pipe" systems are said to be, by those who advocate them, more silent working, but this is a matter of opinion; of course, varying conditions make one preferable to the other, and the engineer's judgment must decide this.

With air we have an element that gives results that, at the moment, are often quite perplexing, but, like other troubles, bad results can be obviated by adopting the ordinary precautions that are necessary in erecting works of this kind. Air is a heavier fluid than steam, and might therefore be supposed to seek a low point when steam endeavours to fill the apparatus, but in practice this cannot by any means be relied upon. Steam is very rapid in its action, and if there are two routes to a radiator, both about equally open, the steam will head the air up and imprison it at some point from which it is more or less difficult to dislodge it. This is, of course, a detail that is considered in the example works, described in a later chapter. The chief ill effect of air is in preventing a radiator, or perhaps a series of radiators, from heating regularly. Air vents on the radiators provide for the expulson of air in the ordinary way, but will not always prove sufficient if the conditions are extraordinary.

In these works, like all other methods of heating whether direct or indirect, it is most desirable to have a full sufficiency of power for the results required. Where first cost is a primary consideration economy is carried to such an extent that, although the desired end may just be gained and the apparatus just do what is expected of it, it is by no means effected with a minimum of fuel and attention, or freedom from noise, etc. This is not satisfactory to those who use and depend upon the apparatus afterwards, and the least neglect brings results that are put to the discredit of the engineer.

Boilers may well be a size larger than is absolutely necessary as they can then be worked with a slower draught, with less attention. (*See* BOILERS.)

The mains and distributing steam services must always be of sufficient size, and an apparatus has never been prejudiced by having the pipes one or even two sizes larger than is absolutely necessary. The reverse is the case in fact, for a fully large pipe is decidedly beneficial. (Suitable sizes will be found given for the different systems.)

The radiating surfaces, whether direct, direct-indirect, or indirect, should always be sufficient, otherwise any extra expense devoted to the boiler and services will be of no avail. A sufficient area of heat-distributing surfaces not only insures efficiency in the ordinary way, but with reasonable attention at the boiler, efficacy is gained with pronounced economy of fuel. (*See* QUANTITIES.) In other words, the proportions of an apparatus at all parts must be correct, and to have the proportions of the boiler and pipes rather full is the best plan. Should any one part be larger than is necessary there is little risk of its being a source of trouble, but to err the other way is a fault always of a serious kind. Should it not make the apparatus fail, it will entail greater expenditure of fuel and labour.

The regulation of a steam heating plant is not so easily effected in the rooms as a hot water apparatus. The stop valves at the radiators have to be full open or shut, and the heat distributed has therefore to be the maximum or none. This is due to the condense water, as there would be no difficulty in regulating the flow of steam alone. With a one-pipe connection the single valve if, say, half closed reduces the steam supply satisfactorily, but, it then becomes too small for the return passage of the condense water also. With a two-pipe connection the two valves would have to be regulated precisely alike, to properly balance the pressure at each end of the radiator, and this is scarcely possible. The range of useful temperature is therefore very limited indeed unless a room has two or more radiators in it, as it is then possible to shut off a portion of the heat as required. With a hot water apparatus the heat can be regulated by attention at the boiler, but this not possible with steam, as steam (low pressure) must either be at its full temperature or have no existence.

It has been recommended to vary the heat of the steam (to suit the weather) by varying the pressure. This would mean manipulating the weight on the lever of the safety valve. This is scarcely practicable; and as nearly all boilers for this work now have the automatic draught and pressure regulator this would require to be altered also. It would not be possible for anyone employed in a residence or a church or small institution to do this; it would require an engineer, and then the variation of temperature obtained would be limited. This fault, however, (if it can be considered a fault) is not so serious in practice as it reads. The regulation of the heat can generally be managed by some means, but it may not be so simply done at the boiler or at the radiator valves.

As regards the cost of erecting these works, compared to hot water installations, a great deal could be said, but from an impartial standpoint, the advantage lies with steam, unless the most complete form of gravity system be adopted. With this every radiator has a separate return pipe (for condense water) extending down to the main return in the basement, and although this may be considered the best of all ways * of carrying out these works, its cost is higher than perhaps any other method of heating. On the other hand, there are engineers of considerable repute who plainly state that the one-pipe system is not only as good as, but distinctly better than all others, and the cost of erecting this is perhaps cheaper than any other recognised mode of heating, except fire-grates.

As regards stoking and attention to a steam heating apparatus, a great change and improvement have been affected by the adoption of the automatic draught and pressure regulator.

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* Advocates of different systems naturally claim the highest degree of perfection for their particular works over all others.

This automatic regulator controls the damper and causes the whole apparatus to work in a more uniform way than even fairly skilled stoking could do, and the results are good accordingly. Equipped in this manner a steam apparatus is considered quite suitable, and is put into private residences, the only attention it needs being that which a female servant or page-boy can easily give.

Steam heat is in regular demand for large works, being preferred to hot water by some architects and authorities. For Turkish baths it is perhaps preferable to everything. For affording quick result, it is not to be equalled. For drying and similar commercial uses requiring a high temperature well maintained, it is better than hot water, and generally preferred to stove-heated air. When exhaust steam is to be had, as is usually the case in manufactories, it has economical features of a very superior kind, and there is every prospect of steam heat superseding hot water for many purposes.

It will doubtless be interesting to set out the opinion of an American engineer upon the various modes of heating, embodying as it does the different kinds of steam apparatus. It is written very moderately and bears evidence of a thorough knowledge of the subject. For the purpose named, the heating of a large school building, most engineers in England would be of the same or a closely similar opinion. The writer is W. H. Bryan, of St. Louis, and the information given has reference to heating a large school building, as just stated.

First, open fireplaces or grates: These are very low in first cost, furnish some ventilation, occupy no space, require no skill to operate, and add a comfortable and homelike appearance to a room. They are, however, expensive in fuel, and the distribution of the heat is so poor as to make them unsuited for this purpose.

Second, stoves: They also are low in first cost and need no skilled attendance. While the fuel cost is lower than for grates, and the heat distribution somewhat better, they are still so inefficient in these respects as to be unavailable in this case. Furthermore, they occupy considerable space and provide no ventilation.

Third, hot air furnaces: These consist substantially of a large stove, located usually in the cellar and surrounded by an air chamber with flues leading to the different rooms, a supply of fresh air being furnished the chamber from outdoors. They are reasonable in first cost, furnish some ventilation, and require no skilled attendance. They are, however, expensive in fuel, need frequent repairs, and it is difficult and often impossible to secure a uniform distribution of heat throughout the building, the distant rooms and those most exposed to winds being the ones which suffer. The system can be improved somewhat by adding vent flues from each room to remove the cool and foul air. These flues are sometimes heated by small stoves to insure circulation.

Fourth, direct steam: This system includes a boiler in the basement, with pipes leading to and from radiators located in the different rooms. It insures a uniform distribution of heat and low cost in fuel. It is, however, expensive in first cost, requires some skill to operate it, and provides no ventilation.

Fifth, direct hot water: This system is designed on substantially the same basis as the steam system, except that hot water is the circulating medium. It has the same advantages and disadvantages. Its first cost is somewhat greater, but it is more economical in fuel and has the advantage of furnishing a more moderate degree of heat in the spring and autumn months.

Sixth, indirect steam: this plan is similar to case 4, except that instead of placing the radiating surface in the different rooms, it is all located in the basement. Fresh air from outside passes over the coils and is thence distributed throughout the building in the same manner as from the hot air furnace described in case 3. The system provides ventilation and is reasonably economical in fuel. Its first cost is considerable, however, and some skill is required in its management. It is to some degree open to the same objection as furnaces in regard to distribution of heat.

Seventh, direct-indirect steam : This system is essentially the same as those described in case 4, except that each radiator is provided with an independent cold air supply. The system provides good ventilation and is reasonably economical in fuel. It is, of course, expensive in first cost, and requires some skill in its management. To insure the best results vent flues should be provided, and they may also need to be heated to insure circulation.

Eighth, warm blast: This system, which is now coming into extensive use, represents perhaps the most intelligent and efficient plan which has yet been devised. In large buildings containing large numbers of people it is undoubtedly superior to all others. It consists of a steam boiler in the basement supplying a stack of heating coils near by. A fan, driven by a small steam engine or an electric or other motor, takes fresh air from outdoors and forces it over the heating coil, from which it is distributed to the different rooms, as in the hot air and indirect systems. There should be a by-pass around the heating coils with a connection to each flue so that cold air may also be blown into the rooms. At the base of each flue there is a mixing damper permitting hot or cold air, or any desired mixture of the two, to enter the flue. The position of this damper is controlled from the room itself, either by hand or automatically. Vent flues are provided in each room for the removal of foul air. The air pressure throughout the building is slightly above that of the atmosphere, thus insuring proper distribution to all parts of the building. A uniform temperature is maintained in each room by changing the position of the mixing damper, but the quantity of air delivered per minute for purposes of ventilation is always the same. The air may be filtered, moistened and cooled if desired. This system is more expensive in first cost than some others, and usually involves a somewhat greater fuel outlay, due principally to the large quantities of air which are heated. It also requires some degree of skill in its manipulation. It is, however, the only system which at all times insures thorough ventilation and heating without regard to wind or weather.

Ninth, combination systems: These consist usually of combined direct and indirect systems of steam and hot air or hot water and air. A great variety of arrangements is possible. In small buildings, where it is necessary to keep down the first cost, while still insuring a reasonable amount of ventilation, they have special advantages. It is not impossible that in this case the best solution may be found in some combination of the indirect systems with a little direct steam radiation for each room to insure proper distribution of heat.

Where I have described a system as expensive in first cost and requiring skilled attendance, these terms are simply intended in a relative sense. The systems costing more always give the best results. None of them require a greater degree of skill or care than we have a right to expect of any janitor of ordinary intelligence.

CHAPTER II.

THE DISTRIBUTION OF HEAT.

In affording warmth to an enclosed space, whether it be merely a closet, a room, or a large hall, there are practically but two ways by which the heat can be distributed from the heated surfaces. One is radiation, the other convection. This is supposing the heated surfaces to be of a kind favourable to these actions going on. But prior to the heat being at the surface ready for distribution, it has to pass through the walls of the pipe or radiator, and a different action—conduction—is required to allow of this. Fortunately iron, which is commercially common and cheap, ranks and acts as a good conductor and imposes practically the least possible barrier to the transference of heat from the inside to the outside of a pipe or radiator tube.

In the case of radiation, the resulting effect depends on the nature of the radiating surface. The heat on reaching the outer surface of the radiator, does no useful work if it stays there, and the nature of this outer surface governs the rate at which this heat is distributed into the room. In other words, it has a great deal to do with the efficiency of the radiator and apparatus generally.

It is agreed by all authorities, that it is the extreme outer surface or skin that governs the degree of heat radiated, and this to a wide extent. Having, therefore, brought the heat to the skin by conduction, it is important that the surface be of a nature that will distribute it freely, or the heat will be imprisoned as successfully as if the surfaces were purposely protected to save loss of heat.

The table here given will show that a bright surface is the least effective heat distributor, and it is said that copper kettles and cooking vessels are kept bright purposely to increase their effectiveness by retaining the heat of their contents. Whether done with this intention or no, the result is correctly stated, a result which is just the reverse of that required at a radiator. With this latter we require the utmost waste of heat from its exterior surfaces, otherwise it will not be effective.

The recognised table of radiating values of materials is as follows:—

Lampblack	100
White lead	100
Water	100
Glass	90
Cast iron (natural surface)	60
Tarnished lead	45
Cast iron, polished	25
Zinc, ditto	19
Wrought iron, ditto	23
Clean lead	19
Silver and copper (natural surface)	12
Brass, roughly polished	11
Brass, highly polished	7
Copper, cast or deposited on iron	7
Silver and copper (highly polished)	3

The radiating and absorbing powers of materials are equal, so that any substance that will absorb heat readily, will just as freely diffuse it again, and *vice versâ*.

From what can be learnt of American engineers' practices in both steam and hot water heating, they scarcely ever leave a radiator in a conspicuous position without decorating it with bronze powder. This material is quoted for, and figures in all their radiator makers' lists, but, apart from the results not suiting every one's tastes, a coat of bronze powder is opposed to the best results. In the table given it will be seen that roughly polished brass, also cast and deposited copp all figure very low in radiating efficacy. Bronze powders b a very close relationship to these two materials, and give practically no better results.

We are assuming the radiator is of iron as usual, a most capable metal as stated, but which cannot be left in its rough and bare state. We have therefore to give it a decorative skin or coat, and it is in the choice of this exterior surface that care must be exercised. In the table of radiating powers glass has a high percentage of efficacy, but, were it possible, a coat of this material would not do as it is such a poor heat conductor. It would be a barrier to the heat getting to the exterior surface for radiation. Fortunately, paint materials, particularly the earths and metallic oxides, offer no resistance to the free transference of heat through their substance on a radiator, and white lead nearly always being an ingredient present good results are assured. Oils also stand even higher than lampblack in radiating efficacy. In other words, a radiator can be decorated with painted colours, and given a good finish with varnish, and stand high in radiating efficacy.* This gives a wide range of decoration as regards colour and combinations of colours; whilst bronze powder, gold leaf and similar metallic materials can very well be avoided. If the writer may express an opinion, confirmed by actual experience, bronze powders exhibit rather poor taste in this work.

Radiant heat, or we might call it projected heat, is given off, or projected, in straight lines from its source, and this happens independently of air currents or similar phenomena. If the radiating surface were a sphere—a ball—then the radiant heat would be given off equally in every direction, top, bottom, or sides. The sun's heat reaches us as radiant rays, and these come in direct lines to the earth. If their path were not direct, then a tree or similar object would afford us no shade. The sun's rays which do not impinge on the earth go straight past it to afford warmth to some other planet or be lost in space. Although we recognise but one visible surface of the sun, we know that it is distributing heat from the opposite side, also from all parts of its surface. As a final proof of the direct course which radiant rays pursue, we have the effects of the ordinary open grate fire. This affords direct warmth* by radiant heat only, and should the heat be too strong for anyone sitting near the fire, they have only to interpose a screen of some kind to cut off the heat effectually.

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* Enamel paints may be used.

With a radiator placed against the wall of a room as Fig. 4 (end view), the radiant heat is freely projected from its front side, but on the other side the radiant heat impinges on the wall only. This latter, however, occasions very little loss of heat as the wall is a poor conductor, and first receives, then re-radiates the warmth into the apartment. It might be likened to a rebound of projected heat, but rather slow in its action; it is really absorption and then re-radiation.

All that has been stated bears particular application to radiators that are visible objects in a room, whether direct or direct-indirect (ventilating); but so far as getting the utmost efficacy, it can as well apply to indirect radiators or coils. These latter afford no radiant heat to the rooms, but they can afford a high temperature to the walls of the chamber containing them, and these surfaces are thus rendered useful assistants to the work in hand. Coils in these hidden places are best coated with lampblack, and it is always desirable to place them so that dust and dirt can have no lodgment. It may be stated here, that dust and dirt of every kind consist chiefly of poor heat-conducting materials, grit (silica, etc.), wool, cotton, wood fibre and similar materials, all of which could be recommended for conserving heat and preventing its loss from the pipe surfaces. This would be a result exactly the reverse of what is desired at a coil or radiator.

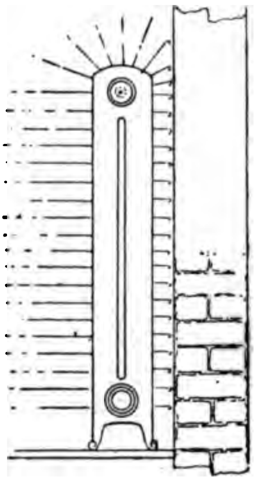

FIG. 4.

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* We get indirect warmth by contact of air with objects which have been warmed by radiant heat, for radiant heat does not warm the air.

It would be desirable, however, with the mains and branches as previously explained.

A last word in regard to radiant heat relates to its healthfulness. It is undoubtedly the most agreeable and beneficial to the human economy, and should be attained wherever possible. It is largely on this account, that indirect works, and particularly hot air works—the air heated by a stove—are objected to, for they afford none of the advantages of radiant heat, and have certain faults that will be alluded to directly.

It is recognised that the body can with comfort bear a comparatively high temperature, while it requires at the same time, to make that comfort complete, a cool or cold air to breathe. Radiant heat affords this rather complex result, as no other mode of heating can.

If radiant heat warmed the air, then our atmosphere would be of a very high temperature on a midsummer day. To prove the contrary, we could on that same day, by ascending in a balloon, find that the air is bitterly cold as we get away from the earth, although we should be all the time approaching a little nearer to the sun.

It is the watery vapour in the atmosphere near the earth's surface that makes the air of a temperate warmth. This vapour first tempers the fierceness of the sun's rays as they reach us, then it prevents instantaneous loss of heat by re-radiation, which would otherwise occur, and does occur, at the summits of mountains where the air is less humid.

The other good feature that radiant heat has in not directly affecting the temperature of the atmosphere, is that it does not affect its humidity either. This latter quality of the atmosphere has to be considered with indirect heating works which increase the heat of air as it passes through the heating chamber, but which does not increase its humidity in proportion, as it should properly do. A table in the Appendix will show what proportions of water vapour air at certain temperatures requires. It is not merely what it can carry, but what it actually needs to make it acceptable to the lungs and health generally. Air at 40° F., which may with its complement of water vapour be healthful and pleasant, has its character changed if heated to say 65° F. If it has no moisture added it will now be an unmistakably dry air, with unpleasant characteristics, for it should have a little more than double the quantity of water vapour in it than when at 40°. To any one suffering with bronchial or lung affections it will be as bad or worse than an east wind in its irritating qualities, although, as stated, at 40° F. no fault could be found with it.

Radiant heat cannot even with the greatest carelessness ever taint the air, as is possible with indirect heating under careless conditions, but on the other hand it does nothing whatever towards affording movement of air, or ventilation. On this account it cannot be considered a failing that the action of convection accompanies radiation in all kinds of steam heating works, for this action has wholly to do with air movement, due to warmth imparted to it.

Convection plays an important part in all heating works except open fires, but even with these latter convection is accountable for the draught in the chimneys.

The action of convection, whether the fluid be gaseous or liquid, is this. The molecules or particles of which the fluid is composed are in all cases extremely mobile, being able to move around and about one another without friction or resistance. If we apply warmth to the air at any point, the particles which are heated expand and become larger than their fellows and are thus rendered lighter, bulk for bulk, than the cooler particles. This being so they are instantly compelled to rise, the same as any foreign substance is in a fluid heavier than itself, a piece of cork plunged in water for instance. It is the cool heavier particles that displace and thrust the warmed particles upwards, and this requires to be borne in mind if problems or difficulties occur. The notion that warmed air, or water, has some inclination of its own to pursue an ascending direction, is common, but quite wrong. If the fluid, hot or cold, could be kept at the same temperature everywhere it would be motionless.

With direct heating radiators (those placed in rooms without being associated with any system of air supply or ventilat we should, to best benefit by the radiant heat, place then equal distances around the sides of the room, or else about centre area. This, however, would not be the best way of utilising the convective action unless it was only the air of the apartment that had to be warmed over and over again. This is never the case, as some means of ventilation is always provided. In the case of a chimney extracting air from a room, the fresh supply of air will probably come in at the door and through the window crevices. In this case a radiator to intercept the draught through the doorway does the very best service, and one under the window is the next best. If the room requires more than two radiators they can be distributed elsewhere as seems desirable. It may be explained that the radiator by the door not only robs the draught of its coldness but it does away with the draught itself. We do not get draughts of warmed air, as they cannot exist unless due to some mechanical force. The ordinary draught, when warmed, takes the character of a wave and moves in a different manner, and although the air is still passing through the room, it no longer hugs the floor and is no longer noticeable.

With "direct-indirect" ventilating radiators, there is special provision of air-inlet or supply; outside air having free passage into the room at one or more points where the radiators are situated. The radiator is of a kind (*see* RADIATORS) that admits of air passing through and having the necessary contact with its heating surfaces and so receiving warmth. The air is thus delivered into the room at an agreeable temperature. This inflow, however, is dependent on there being outlet ventilation of some kind, for air will not by natural causes enter an apartment already full of air. There must be a regular extraction of air from the room (supposed to be vitiated air), and then there will be a proportionate inflow of new air through the radiators. The doorway does not require consideration, as the open means for air ingress at the radiators quite prevents any serious draught being created through the door aperture. With these radiators we get radiant heat projected into the room as much as from the others, and they are "direct" heating in this respect. Their "indirect" action is in dealing with all the air entering the room, resembling heated air works in this respect, hot air works being classified as an "indirect" mode of heating. The radiator just referred to, is therefore a combination of the two, as its name implies.

These radiators thus require for their particular purpose an extraction of air from the room (by an efficient chimney or ventilating flues, or mechanically), otherwise new air cannot enter. And the new air must, by the design of the radiator, be brought into intimate contact with the heated surfaces, or its temperature will not be appreciably raised. Should the air extraction fail, or be insufficient, and the inflow of new air be reduced accordingly, then the radiator will still do good work, acting, wholly or partially, more like a "direct" heating radiator, as already referred to. If, on the other hand, the air extraction is too great, the inflow will be more rapid than the radiator can properly deal with in the way of affording it warmth. This has to be settled in the choice and purchase of radiators, the makers guaranteeing the degree of efficiency in this respect. If there is insufficient extraction in residence works it does not seriously matter, since the air of ordinary reception rooms is not very rapidly vitiated. In public rooms the reverse of this applies, as the inlet apertures can be closed to warm the place, when empty, and afterwards ventilation is more important than the heat, since the assembled people add to the warmth of a place as everyone knows. In these radiators a greater area of radiating surface must be provided than if the "direct" heating kind are used, as will be seen in the chapter on QUANTITIES.

Indirect heating is that in which the heat-distributing surfaces are out of sight, and the warmth received in the room is that of heated air wholly—not direct radiant heat. The pipes or coils, which warm the air, distribute radiant heat the same as radiators do, but these rays are confined to the box or chamber in which the pipes are situated. They impart heat to the walls of the chamber, and these warmed surfaces aid in increasing the temperature of the air, so it cannot be said that there is any very noticeable loss of heat: it is that the radiant heat—a form of heat that ought not to be dispens with if possible—does not reach the rooms that are be warmed, only heated air being received there.

There are two ways of carrying out indirect heating works, one being to have a central heating chamber which all the air first enters, from which it is then distributed to the points where it is required, by sheet iron or zinc tubes. The other is to have coils in ceiling or wall boxes beneath the rooms, the warmed air passing up through grated apertures in the floor above. In either case some system of outlet (extract) ventilation is absolutely necessary, otherwise the warmed air, at the best, will move but very sluggishly. The ventilation may be that of exhaustion by flues or mechanically, or it may be on what is termed the *plenum* system, the warmed air being mechanically forced into the apartments. With coils in floor cases, there may be tubes provided to convey fresh air to them, and thence into the rooms; or they are sometimes used without this provision. This plan can only be adopted when the rooms below are unimportant, cellars or kitchen offices, as the coil boxes are by no means ornamental or inconspicuous. In the case of there being kitchen offices below great care is necessary to make the boxes air-tight everywhere, or odours of cooking will be carried through very sharply.

Sometimes, in fact frequently, there is a combination of direct and indirect works to meet special requirements. Certain rooms may have visible radiators, others may not. The radiators at present on the market are not always thought handsome enough for some rooms (in residence or good hotel work), and then either of the indirect methods is resorted to; probably the latter, having the coils in boxes below. This does not in any way interfere with having direct heating radiators in other places, or *vice versa.*

Indirect heating is practised in many cases where it is considered to be absolutely necessary—a sort of necessary evil, for it is not popular. It takes a greater quantity of pipe surface for given results. It is decidedly the most expensive in first cost, and also in subsequent working. With the heating surface in one central chamber, the distributing pipes for the warmed air have to be large, and although they can be square still they are not sightly, and for this form of apparatus the building ought to be prepared in construction. Lastly, indirect heating works, unless there is special provision, deliver the air drier than is desirable, and in some cases drier than is comfortable for respiration. This is referred to more fully in the earlier part of this chapter, and a table in the Appendix gives the amount of moisture present in air at different temperatures, when it has its complement.

It is scarcely correct to convey an impression that indirect heating should be condemned. It depends so much on how it is carried out. In many cases it means a radiator in a box, more or less inaccessible, and which gets covered with dirt. In such an instance the first cost is great and the results bad, for dust and dirt are not only poor heat conductors, which prevent the radiator doing its work, but they can create an odour. Particles of wool and hair, if nothing worse, give off an odour when on a steam pipe.

The reverse of this would apply with a well erected apparatus on the plenum system, in which all parts can be kept clean, temperature of air regulated by mixing the cold and warm airs (not by varying the total volume), and everything done that is favourable to good results. This really amounts to saying that indirect heating is not desirable for comparatively small works, but is good for large installations; and this in a general way is correct.

CHAPTER III.

STEAM HEAT.

HEAT is measured or calculated by units, a unit representing a certain quantity or volume of heat, if it may be so expressed. The amount of heat that goes to make a unit is that required to raise the heat of a pound of water one degree Fahrenheit. For very precise calculations (scarcely ever required by the heating engineer) it has to be calculated that the one degree rise in temperature is from 32° to 33° F., for at other temperatures the amount of heat required to raise the pound of water one degree is a trifle different. The difference, however, is so very trifling that it is never or rarely ever taken into consideration in this work.

The result of this method of calculation is that, taking one pound of water as the standard of weight, we know that each degree Fahrenheit also represents a unit of heat. In other words, a pound of water at 150° F. contains 150 units of heat, and so on up to 212°. At the latter temperature boiling occurs if the water is in an open pan, and there is then no further increase in its sensible heat; that is, no extra heat would appear on a thermometer placed in it. There are, however, a large number of additional units taken up as boiling transpires, these units going to make the latent heat of steam, of which more will be said directly.

This unit is known in all English-speaking countries as the British Thermal Unit or B.T.U. It is quite a small volume of heat, as there are 13,000 units in one pound of good coal, though it may be mentioned that with heat going into the chimney and loss in other ways, not more than about 9,000 units is the best average absorbed by the water.

In most Continental countries the standard or unit is different, being known as the Calorie. This is the amount of heat required to raise one kilogramme of water one degree Centigrade, viz. from 15° to 16° C. The calorie is equivalent to 3·9672 B.T.U., practically four British Thermal Units to the Calorie. This information will be found of great use when dealing with French-speaking and several other countries, as the unit of heat is more largely referred to and quoted than in England. It, is however, always coupled with metrical measurements, and these will be found in the Appendix at the end of this book.

Although scarcely needed in the consideration of steam heat it may be explained that water has what is known as a "specific" heat. This is not calculated in units, as the specific heat is that required to make a unit. Therefore, it has no measurement, only a comparison with the specific heat of other bodies. The way this is expressed is to state that water requires a certain amount of heat (a certain amount of fuel really) to raise its temperature one degree, and this amount can be called 1·000. Or it can be said that if a pound of water takes one B.T.U. to raise it one degree in temperature, then other liquids take the following proportions:—

THE SPECIFIC HEAT OF CERTAIN LIQUIDS (*Box*).

Water . .	1·000	Oil of turpentine	·472
Alcohol . .	·622	Petroleum . .	·434
Ether, sulphuric .	·477	Olive oil . .	·400

This only goes to show that with certain other liquids we could obtain a desired temperature with less fuel than we can get it with water, but the resulting effect and cost would not differ to the extent shown. If a certain temperature is obtained with 10,000 units of heat instead of 20,000, then there is only 10,000 to be disposed of and not 20,000 as there would be with the latter.

Latent Heat.—It is highly essential that the steam heating engineer should be acquainted with the nature and qualities of latent heat. It can be readily found that when water is brought to boiling point, its temperature ceases to rise although it continues to receive heat. The heat thus received is stored up, so to speak, for it is not revealed on the thermometer. Or it might be said that, as water absorbs so much heat as specific heat (just explained), so steam takes a certain known quantity as its specific heat. It may be explained this way, for it is not possible to have steam without expending the required amount of heat over and above that needed to bring the water to the point of boiling. Still another explanation is that the latent heat is necessary for the conversion of a liquid to a gaseous condition, that the gaseous condition is due to and dependent on the heat taken, so that a pound of steam is simply a pound of water plus latent heat. It therefore follows that when the steam is reconverted to water it releases the heat no longer necessary for its existence—repays the borrowed heat, so to speak.

The units taken as latent heat are considerable, being sufficient to have raised the water 966° further if it had not boiled. In other words, a pound of water having 212 units at 212°, takes 966 units more in passing to steam, or 1178 units altogether. For the sake of accuracy it is necessary to mention that a pound of water could not be raised from 0° to 212° with 212 units, because there is a volume of latent heat absorbed when ice becomes water; but this does not need to be taken into consideration in this case, for, like all latent heat, it is only temporarily held. When ice becomes water it takes up 142 units as latent heat, but on reconverting the water to ice this heat would again be liberated.

This has a bearing on the latent heat of steam, for it is only temporarily held whilst the water is in the state of steam as just stated. The 966 latent units are released when the steam is condensed; and as we may assume that the condensation occurs in radiators or radiating pipes, they have all the useful effect of heat units which go to make "sensible"—meaning perceivable—heat that shows itself on the thermometer. It is considered possible to have effective heat from radiators filled with steam at 212°, yet have the condense water returning to the boiler at almost the same temperature. In other words, the successful heating of the radiators can be done almost entirely with the latent heat held by the steam.

A somewhat peculiar detail connected with latent heat, and having a bearing on the subject of this book, is the variation in the number of latent heat units taken by water under different pressures. The peculiarity rests in the fact that high pressure steam, with a high thermometer temperature, does not mean a higher total temperature.

The temperature at which water boils varies with the pressure on it, as already explained, and as will be seen by the table in the Appendix. The number of heat units—the amount of heat—that become latent varies also; but as the temperature at which boiling occurs increases, so the number of heat units taken up as latent heat decreases, and it has been found that the total number of units—sensible and latent—is the same at whatever temperature the water boils. Thus, at atmospheric pressure the total heat units per pound of water when converted to steam is 1178, being 212° taken to raise the water to boiling point, and 966 taken up by the steam as latent heat. If boiling occurs under pressure, say 60 lbs. to the square inch, the boiling point is 307° F., meaning 307 B.T.U. absorbed when boiling point is reached. The units taken up as latent heat, however, are now less, being only say 871, and the total held by the steam, therefore, remains 1178.

The important lesson learnt by this is that high pressure steam, hot as it is, has no greater amount of heat units to boast of per pound of water, and the greater gain supposed to be obtained by steam in this state is less real than it at first appears. The outcome of this knowledge is that low-pressure steam is more favoured, for it does excellent work at the least cost, and the vacuum systems of steam heating now being used more freely, prove to be highly economical and effective. As the uniformity in the total number of heat units in steam is applied to all pressures of steam, it applies equally to steam generated at less than atmospheric pressure. Water boiled in partial vacuum, say at 7½ lbs. to the square inch, this being very close to half the pressure of the atmosphere, has a temperature of 180° only, that is, it has absorbed 180 units when it reaches boiling point. On being converted to steam it takes 998 units for its latent heat, total 1178, so that there is much in favour, of this system of heating when the conditions are generally favourable. The vacuum systems have many other things in their favour, as will be explained later. Steam will more readily enter a partial vacuum than it will go out of an open pipe against the atmosphere.

TEMPERATURES AND PRESSURES.
(Abbreviated from Table in Appendix.)

Vacuum, inches of mercury.	Absolute Pressure (not gauge).	Temperature at which boiling occurs, ° Fahr.	Units in 1 lb. of water converted to steam.
11·6	9	188·3	1171
7·5	11	197·8	1174
3·5	13	205·9	1176
0·0	14·7	212·0	1178
Pressure in lbs. per square inch on the gauge.			
1·3	16	216·3	1179
3·3	18	222·4	1181
5·3	20	228·0	1183
7·3	22	233·0	1184
10·3	25	240·0	1186

It will be seen that this table contradicts, to a slight extent, the information just given to the effect that the total heat units in steam remain constant at 1178 whatever the pressure. As a fact, the figure is not constant, for the total units increase with the pressure, but the variation is so slight that it need not be taken into account in this work. At 60 lbs. pressure the B.T.U. are actually 1207 or 29 units more than just previously stated. This only represents a difference of just over two per cent. for 60 lbs. above atmospheric pressure, and in all ordinary circumstances need not be considered. The rule observed, therefore, in this work, is that steam at all pressures has the same number of units in it.

It may here be mentioned that practically the same number of heat units are absorbed in converting the water of wet clothes or other substances into vapour in a drying room. In other words, the weight of steam necessary to dry goods can never be less than the weight of water dried out of them. It will in fact be greater, as in practice there are losses of heat to be made good.

A pound of steam and a pound of water are in a sense synonymous terms as regards the number of heat units, for a pound of water converted to steam is still a pound, but in its gaseous state it occupies a much greater space. Therefore, a pound of water converted to steam and having then 1178 heat units, is spoken of as a pound of steam, though speaking more definitely, it is a pound of water converted to steam.

The weight of steam (in relation to its bulk) varies with the pressure. At atmospheric pressure, 14·7 lbs., and 212° F. a cubic foot weighs ·0380 lb. and from this it increases in a recognised ratio with the pressure; or decreases if the steam is generated at a pressure below the atmosphere, in partial vacuum.

WEIGHT OF ONE CUBIC FOOT OF SATURATED STEAM (NOT SUPERHEATED) IN POUNDS.

Pressure per square inch.	Weight.	Pressure per square inch.	Weight.
lbs.	lb.		lb.
15	·0387	18	·0462
16	·0413	20	·0511
17	·0437	22	·0561

WEIGHT OF ONE CUBIC FOOT OF SATURATED STEAM—*continued.*

Pressure per square inch.	Weight.	Pressure. per square inch.	Weight.
lbs.	lb.	lbs.	lb.
24	·0610	45	·1111
26	·0658	50	·1227
28	·0707	55	·1343
30	·0755	60	·1457
32	·0803	70	·1681
34	·0851	80	·1901
36	·0899	90	·2118
38	·0946	100	·2330
40	·0994		

It must be noted that the pressures given are absolute and not above that of the atmosphere. A pressure gauge would show 14·7 lbs. less than those here given.

VOLUME OF A POUND OF STEAM AT DIFFERENT PRESSURES.

Pressure per square inch.	Volume in cubic feet.	Pressure per square inch.	Volume in cubic feet.
lbs.		lbs.	
14·7	26·36	20	19·72
15	25·85	21	18·84
16	24·32	22	18·03
17	22·96	23	17·26
18	21·78	24	16·64
19	20·70	25	16·00

Although a pound of coal or coke has a definite and known number of heat units, we cannot hope to get them wholly transferred to the steam. Eighty per cent. may be considered the maximum obtainable, whilst in the majority of cases the percentage will be found well below this. With best Welsh coal, under favourable conditions, it might be possible to get 11,000 units per pound, but for ordinary coal 8000 to 10,000 would be the most that could be relied on. Coke will afford about 7000 to 8000 units per pound. As one pound of water converted to steam takes 1178 B.T.U. it can be easily computed what volume of steam or amount of steam heat a given quantity of fuel will produce. Here, however, is the difficulty experienced in all heating works, for it can only be a theoretical calculation, due to the value of the fuel in heat units being probably uncertain; and, more important, the boiler perhaps being at fault in some detail such as grate area, disposition or nature of heating surfaces, draught, etc.

Having obtained the heat units in the form of steam there comes the question of radiation and loss in the rooms, for the whole purpose of the steam generation is to afford, or to distribute, the heat at some different point to that where it was made. Radiating surfaces have their efficacy governed by the nature of their exterior surface or skin, as already explained (see page 14). This, be it understood, affects the

LOSS OF HEAT UNITS PER HOUR FROM A SQUARE FOOT OF SURFACE, HEATED TO 210° F. AND EXPOSED TO THE AIR AT 60°.

—	Loss by radiation. Units.	Loss by air contact. Units.	Total. Units.
Silvered copper, polished	5·98	133·57	139·55
Tinned iron, polished	19·32	,,	152·89
Sheet iron, polished	20·7	,,	154·27
,, whitewashed	152·7	,,	286·27
Cast iron, rusted	154·53	,,	287·10
,, lampblacked	184·4	,,	317·97

radiation only, and not the heat afforded to the air by contact. As previously explained, radiators afford heat by radiation and by convection, and while the former is controlled by the radiating surface, the latter is not.

In Table 107 of Box's practical treatise on Heat the figures shown on the preceding page are given.

The following table, from Carpenter's 'Heating and Ventilating Buildings,' is more comprehensive:—

HEAT UNITS PER HOUR.

Difference between temperature of radiating surface and air to be heated.	Radiation.		Convection.	
	Total units per square foot.	Units per square foot for each degree difference.	Total units per square foot.	Units per square foot for each degree difference.
°F.				
108	30·2	·281	31·8	·295
126	36·6	·291	38·4	·306
144	43·7	·304	45·0	·311
162	51·2	·317	52·2	·32
180	59·5	·33	59·5	·33
198	68·5	·345	67·0	·334
216	78·0	·361	75·5	·345
234	88·3	·377	82·2	·35
252	99·0	·395	90·0	·355
270	112·0	·416	98·0	·36
288	125·0	·435	106·0	·365
306	139·0	·454	115·0	·372

Rule.—To find the total heat emitted by radiation, multiply the value of a coefficient as given in the following table by the number corresponding to radiation due to the difference in temperature in the above table.

The table of coefficients given includes a number of substances having different radiating qualities, and we need only extract the following as being applicable to practical uses :—

VALUE OF COEFFICIENTS.

Polished silver	0·43	Rusty sheet iron	3·36
„ brass	0·258	Cast-iron, new	3·17
Red copper	0·16	„ rusty	3·36
Zinc	0·24	Oil painting	3.71
Ordinary sheet iron	2·77	Soot	4·01

It may be taken for ordinary calculations, that direct steam heated radiator surface gives off about 320 heat units per foot per hour when the difference in temperature is 160°, say room at 60° and steam at 220°, this being the difference usually existing in low-pressure steam heating works. As the conversion of water at 212° to steam at 212° takes 966 units per pound, it follows that a square foot of radiation requires one-third of a pound of steam to keep it supplied.

The equivalent of one unit of heat, that is raising the temperature of one pound of water one degree, in warming the air, is raising the temperature of 52½ cubic feet of dry air one degree, viz. from 32° to 33°. In other words, the heat or fuel needed to increase the temperature of a pound of water one degree will, if so applied, heat 52½ cubic feet of air to a similar extent. One thousand cubic feet of air therefore takes 20 units to heat it one degree; or from 26° to 60° (the rise in temperature required in ordinary heating) 680 units. As a square foot of radiating surface emits 320 units per hour, when the steam is 220° and the air 60°, it would appear as if two square feet of surface would nearly suffice to heat a room of a thousand cubic feet capacity (or two feet per thousand for any other size of room). This, however, it will not do, as there are conditions to be considered. There must be a change of air several times per hour for an ordinary living apartment, and then there is loss of heat by walls and particularly by glass. These factors are taken into consideration in d mining the figures given in the chapter on QUANTITIES

CHAPTER IV.

DESIGNS OF LOW-PRESSURE STEAM HEATING APPARATUS, GRAVITY SYSTEMS, WHICH RETURN THEIR CONDENSE WATER TO THE BOILER.

THE designs about to be given are almost wholly those of apparatus in which the condense water is returned—that is, runs back—to the boiler. This is styled "gravity circulation" as the piping is done so that the condense water can trickle along it by gravity, eventually finding its way back to the boiler, where it started from in the form of steam. This arrangement has the great advantage of needing no watchful eye to be kept on the water-gauge, for as the water comes back there is practically no loss. This makes an injector unnecessary, and—what is of more importance— it removes the chief likelihood of danger, if the boiler is tended by an unskilled or careless person. A further advantage of no small importance is, that there is no lime deposit made from hard water, as the same water is re-heated and not changed or lost.

What also makes it possible for an unskilled person to have charge of a steam heating apparatus with good results is the Automatic Damper Regulator. This is an American device, and no one thing could possibly do so much to make a steam boiler simple and easy of attention. The regulator does not easily get out of order or fail. This will be described later with some other appliances ("trimmings," as the Americans call the fittings), but it may be stated here that it very simply regulates the draught to the fire by means of the steam pressure. As the pressure rises so the draught is checked, and *vice versa.* Its action is reliable, so that all the stoking needed is to pile the fuel in, and the regulator will keep the pressure constant by regulating the combustion of the fuel.

It will allow just enough fuel to be burned to make the steam for the pressure required and no more. It is almost an automatic attendant; certainly it does the skilled part of the attention, as the fire and pressure gauge do not need constant watching.

The earliest form of steam heating apparatus, having its condense water return to the boiler by gravity, consisted of single pipes only. An idea of this is given by Fig. 5. The boiler occupied the lowest position, as is still necessary, and from this the heating surfaces or pipes were carried in a continually ascending direction wherever desired. It was not possible for the services to drop or dip at any point, nor was it practicable to run them quite horizontally. If they dipped at all, little or much, it will be seen that the condense water must collect at that point and choke the pipe. Even if the force of steam drove it forward, it would soon be back again; or should the vacuum, caused by the steam condensing in the pipe beyond the dip, make the water move it would be no better. None of the forces would cause the entrapped water to move towards the boiler, and this is what is needed.

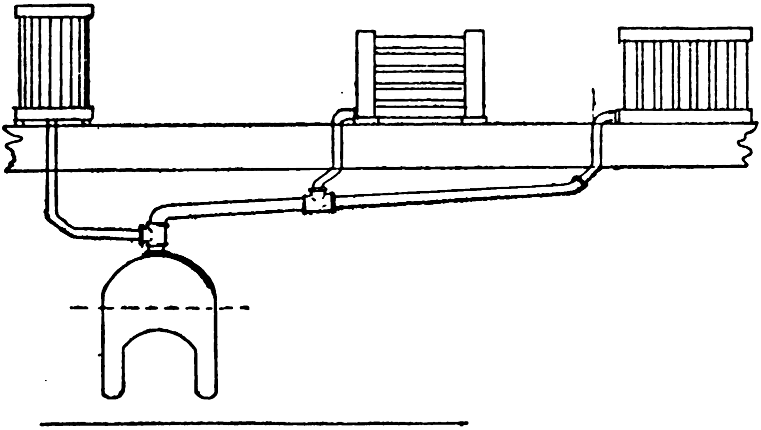

FIG. 5.

To obtain the gradually ascending pipe is not very d cult, as it is continually being done with hot water wo

The chief fault rests in the fact that with pipes disposed in this way, the steam and the condense water must of necessity move in contrary directions. The steam passes up the piping from the boiler, the condense water comes down the pipes towards the boiler, and at all parts the two are passing one another in opposite ways.

All works of this kind are now specially designed to cause the steam and condense water to travel together, wherever possible, both in the same direction. It is almost the chief thought of the engineer, and fortunately it is quite easily done. When steam and water pass in opposite ways it is only by using large pipes that conflict between them can be avoided, and even with large pipes the rise or fall has to be greater than otherwise, to ensure quiet working. With these two provisions—fully large pipes and a good rise from the boiler at all points—it would be possible to have a successful apparatus of the design of that just illustrated. As, however, the large pipes cost more than the smaller ones used with a more modern apparatus, and with the latter the steam and water can be made to travel both one way, the old single pipe apparatus can well be abandoned.

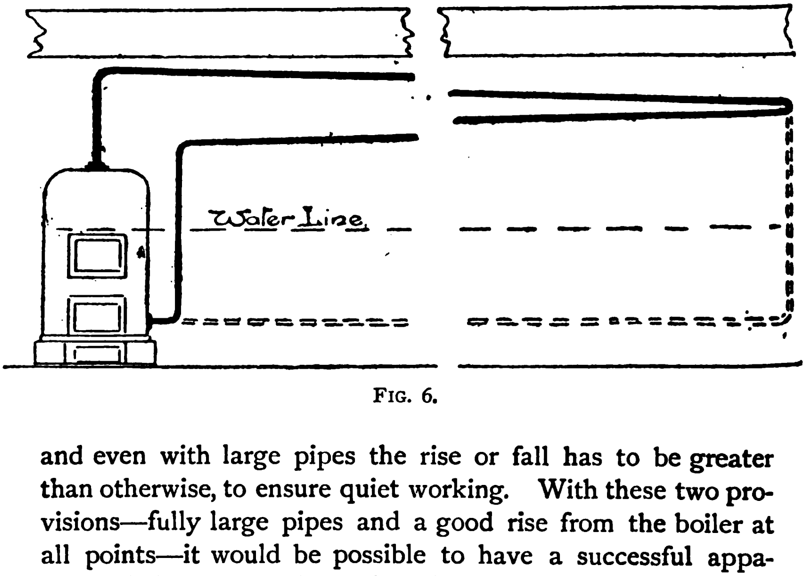

FIG. 6.

The steam heating apparatus which has its condense water coming back to the boiler through a different opening and pipe to that which the steam passes up, is quite a simple arrangement. It is just a flow and return as Fig. 6: sometimes with the return as shown in solid black line, which is then called a dry or overhead return ; sometimes as in dotted line, which is known as a wet or submerged return. The purpose of the two will be explained later, but briefly it may be said that the overhead return is usually with one-pipe connections, and the wet return for two-pipe work. The cold supply is merely a pipe from the house service, or main, with a stop-cock. When a little water is needed, say once a week, the cock is opened when steam is not making, and what water is needed is allowed to flow in.

The sizes of boilers, pipes (main and branch), radiators and connections are all decided by rule, so that with ordinary care very little error should be made in these details. Where skilled experience is needed is in disposing of the condense water; and although it sounds very simple to say let it run back to the boiler, it does not do so at all willingly unless the engineer knows how to make it go.

If an apparatus had to be erected as Fig. 6 with from three to six radiators on it, almost anyone could do the work and guarantee success. It is so easy with a simple model like this to arrange that the steam and the condense water travel together, both in the same direction, and this is where success is largely secured.

Success is initially secured by getting a fall to the mains practically everywhere. The highest point of the piping must be as close to the boiler as it can be got, for wherever the pipe rises away from the boiler there the steam and condense water have to pursue opposite directions in the same pipe, and this favours troublesome results. The possibility of trouble may be minimised by well coating a rising pipe so that condensation does not occur in it, but this is not so good as dispensing with the rise if possible. This applies to main services. With radiator branches the trouble can be obviated by using a larger pipe than the steam needs, so as to accommodate the water and allow the two to pass one another without conflict or commotion.

The way in which the trouble that condense water c cause manifests itself is, firstly, in preventing a circulation of steam, and secondly, in causing alarming noises. These noises are sometimes accompanied by such force and strain as to be a source of danger.

There have been accidents, and it is discovered that the weakest points in the apparatus are usually at the valves. In stopping the steam circulation it is a collection of condense water, pocketed or held up somewhere, that causes the fault, and it is this which makes the noises possible.

Some doubt is felt in accounting for the noises, for although it is possible to explain the actual cause it is not by any means easy to say how the cause originates. It may not be twice alike. However, the noise, a pounding or water-hammer, is not caused by the steam, as this is so elastic and accommodating. It is caused by the condense water entering a vacant space, a space devoid of steam, air or water, a vacuum, and it enters here with considerable violence. Water, it must be understood, is practically incompressible; iron can be compressed more easily than water, for instance. This being so, water can be projected into a space and deliver a blow just as if it were a mass of metal, causing the pipes to vibrate and give every evidence of rough usage apart from the noise, which there is no mistaking. The entrance of water into a vacuum space can happen as follows. Water may be pocketed in a little depression in a pipe, and the flowing steam work or force past it. If this steam is then condensed a vacuum will be formed and the pocketed water instantly projected into the space. Or should there be water further on it may be brought back, and perhaps the two bodies of water meet. In either case this sudden occurrence will probably disarrange the uniformity of pressure in other parts of the apparatus with more or less disagreeable phenomena. It may reasonably be assumed, in many cases, that a noise or fault in one part of an apparatus may be primarily due to a fault at some other point, this primary fault very likely being much less noisy or evident.

Faults in steam heating work are usually hard problems to solve, and it is distinctly best to erect the apparatus with great care in the first place and so prevent them. Prevention is ever so much better than cure in this work.

Of the different systems in use it is probable that the one-pipe has the greatest favour, for it is more easily erected and costs least. It cannot be said to be suited for every requirement, but it can be adapted in quite the majority of instances, particularly in small jobs. Many American engineers consider it a system that excels all others in good results, and, as steam heating is practised so largely in America, the engineers of that country are worth listening to. Large city buildings of great extent and many floors are heated with one-pipe steam apparatus, and the utmost satisfaction is experienced. On the other hand, it is a very eminent American engineer who says that only a two-pipe system with wet return can be guaranteed as noiseless, as only in that system can the steam and condense water be made to work in harmony, travelling together at practically all points. As stated, it is the absence of noise that has to be counted as an important detail in the general efficacy of the apparatus that is erected. In most cases it might be said that a noiseless working apparatus could not be a failure in any other respect, for a noiseless working apparatus is a fairly correct index to the skill and knowledge of the engineer who erected it. In any event a one-pipe apparatus, if properly erected, gives no trouble, and its advantageous features of simplicity and lowness of cost greatly recommend it.

The one-pipe system.—With this piping system it is only at the radiators and their branches that a single connection or pipe is used. From the boiler out to the work and back again there is a circuit, a flow and return in reality, and this also exists in the two-pipe and other named systems. The terms one-pipe and two-pipe can, therefore, only apply to the piping connected and run from the main circulation. This will be seen from Fig. 7, which shows as mall and simple one-pipe apparatus.

Before proceeding further it is desirable to give the names by which the pipes of a steam heating apparatus are known, as this will make the description much more clear.

The pipe leaving the top of the boiler and which receives and conveys the steam is known as the "st main." It corresponds to the main flow pipe of a hot water apparatus.

The pipe which brings the condense water to the boiler is simply called the main return, but it may be a "dry" or a "wet" return. The dry return is carried above the water level in the boiler until it drops down to be connected, and is not infrequently called an overhead return. The wet return is brought along the floor of the basement below the water line in the boiler and is always full of water. This is often called a submerged return on this account. A wet return is not required in the one-pipe system as the radiators have no return pipes from them.

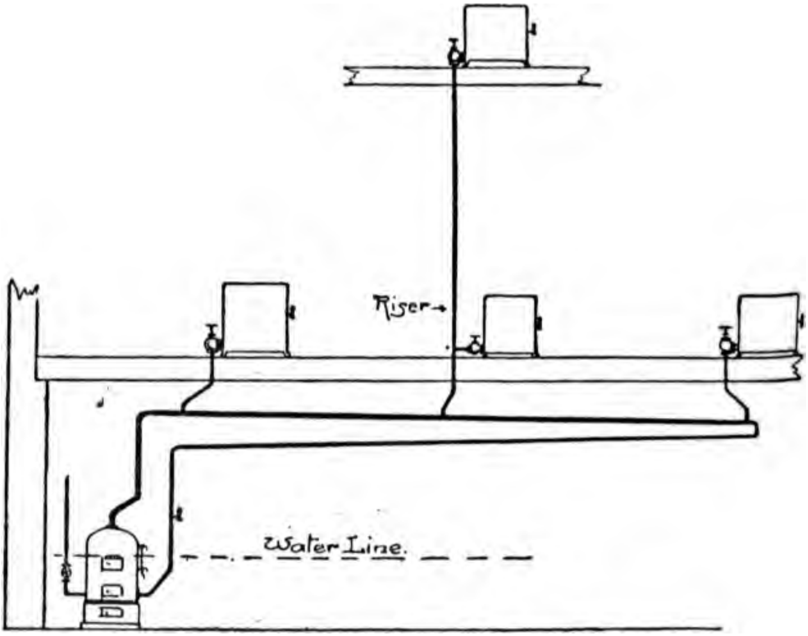

FIG. 7.

A vertical pipe extending down from the supply main to the return main, at any point, is known as a "relief." Its object is to relieve the flow main of condense water.

The pipes which go up from the supply main are either radiator branches or risers. A pipe which just goes through the floor to supply a radiator is, of course, only a branch, but a pipe which goes up one or more floors having two or more radiator branches from it is a riser. A riser is, in fact, a vertical branch supply main, whereas a radiator branch supplies one radiator only.

There are in two-pipe systems also "supply risers" and "return risers," but in the one-pipe system the word "riser" is sufficient, as will be seen. This is all that need be explained regarding the names at present, and they are in fact all that have common use. Special names given to unusual connections can be mentioned later.

In the sketch, Fig. 7, which is the simplest form of apparatus that can be devised, it will be noticed that both the supply main and its return are run with a fall. The supply pipe does not rise to its furthest point like the flow pipe of a hot water apparatus. It rises directly from the top of the boiler as high as convenient at that point, and then commences to fall to its further extremity and back to the boiler. The fall should never be less than one inch in twenty feet, and it is best to make the minimum one inch in ten feet whenever possible.

Assuming the boiler is in a basement, then the supply main is carried up close to the ceiling at once, and from this point it falls all the way to the boiler. This ensures the steam and condense water travelling together through the whole length of the main service except the two or three feet from the top of the boiler to the highest point just above it.

In this two or three feet of pipe the steam and the condense water travel in opposite directions, the steam passing up, the condense water trickling down; but the quantity of water in this short piece of pipe is not sufficient to cause trouble if the pipe is of correct size. Furthermore, this piece of the main service, and all of it in fact, should be covered with some material to prevent loss of heat and useless condensation. It is of greater importance to cover these pipes than with hot water works, for coldness means loss of steam and total loss of the warmth it would give, and the condense water has t disposed of.

After the supply main has passed the last riser or radiator branch it is immediately returned to the boiler, as shown, being connected there well below the water line. It will be noticed that in this apparatus, as with all that may be styled circulating systems, there is no waste of water and no condense water traps are needed. The consequence of this is that the water level, or water gauge, does not want constantly watching, nor is it necessary to have any special device to fill the boiler or replenish it. What little loss of water does occur can be made good when steam is down, and it will not need doing but about once a week. Any steam heating system that has to have a trap and discharge its condense water, or some of it, needs a watchful eye at the water gauge, and probably an injector or pump for the water supply. This cannot be avoided sometimes, and its makes a skilled male attendant necessary; whereas a circulating system, particularly if there is an automatic regulator on the boiler (to be explained later) can be attended to by a female domestic servant if the apparatus is on a suitably moderate scale.

A detail of importance in the piping of a steam apparatus is the allowance that must be made for expansion and contraction. This requires to be considered much more than it does with hot water works, for two reasons. The first is that the difference in temperature of a steam apparatus when cold and hot is about 40° greater than with hot water, and the expansion and contraction are proportionately more. Secondly the lengthening and shortening of the pipes with heat and cold occurs in such a very brief space of time; with steam it is quite sudden compared to the heating up of a hot water apparatus. This causes serious strains, and quite ordinary strains are made serious when so abruptly exerted. With hot water the expansion and contraction are so slow and gradual that if resistance is experienced it is quite the usual thing for the pipes or other parts to be able to accommodate themselves to one another, a thing that is not so likely when the phenomenon is manifested so quickly.

To provide for this, all connections to rigid points are made to swing or give. Rigid points are, for example, the boiler and the radiators. It was said that the supply main always rises directly from the top of the boiler to the highest point. This is correct in a sense, but it should never go straight up. It must be as Fig. 8. This is not done to allow for the expansion of this rising piece of main, but to allow for the push or pull of the horizontal part. If it is necessary to allow for push and pull in a vertical main (where a main has to go direct up one or more floors), the boiler connection would be more as Fig. 9.

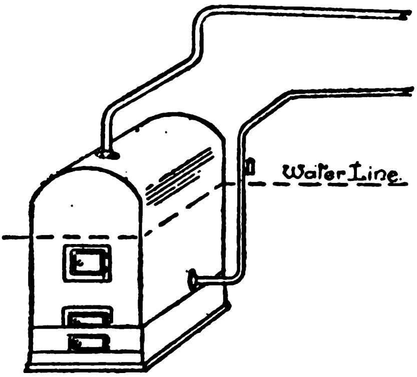

FIG. 8.

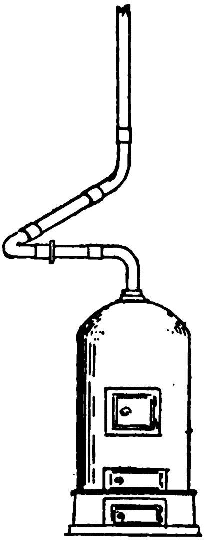

FIG. 9.

A radiator branch has to be connected up as Fig. 10; this is a swing connection, not to provide for any push or pull in the branch itself (as it is assumed the branch is too short to require the provision), but to allow the long horizontal mains to push and pull without finding rigid resistance at the branch connections. It is customary to call this a swing joint or connection, but the word spring would perhaps be better adapted to it. It is a manner of making a connection with joints that will not break or leak when strained to a reasonable extent.

Where the mains, or any steam pipes, run in a straight line for more than 50 feet, it is desirable to introduce an expansion joint or piece; unless the pipe should not exceed, say, 70 feet or 80 feet, and its two ends can be arranged to give to the expansive and contractive force this length of pipe exerts each time it is heated and cooled. There are many devices provided for this: one of gun-metal working like a tubular piston rod in its case and kept sound with a stuffing box; another is a piece of copper pipe bent to the shape of a long horseshoe. This is inserted in the run of pipe, and it springs in or out with the push or pull of the pipe. It is, of course, fixed flat, not looping up or down, so that it does not pocket the condense water or interfere with its free flow. It is not considered to be so good as the piston, as some engineers find the tube of the horse-shoe will not bear the springing for very long. This, however, may be caused by a poor economy in having the loop too short, so that it does not spring without considerable strain.

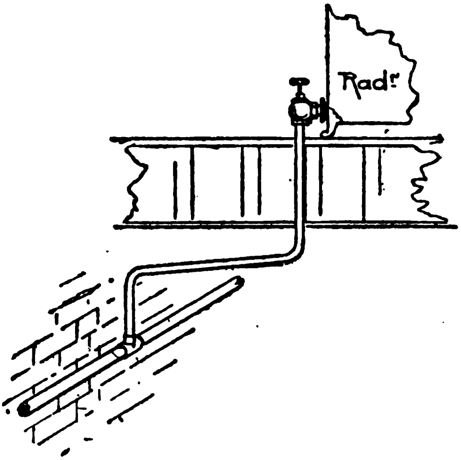

FIG. 10.

A method that is cheap, and has much in its favour when possible of adoption, is to break the continuous run of the pipe here and there. Supposing the main was along a corridor, or the ceiling of a basement, then every 40 feet or 50 feet, let it turn to right angles for 4 feet or 6 feet, depending on the size of the pipe, run along straight for another similar distance, then turn back to its original line. Fig. 11 gives an idea of this, it being the view of a basement corridor with the ceiling removed and with the steam supply main run along first one side then the other, each break in its continuity affording a spring for the expansion and contraction of the pipes. It is important that proper pipe supports be used, not merely a hook driven into the wall and gripping the pipe there. There must be rigid hooks or eyes, but which allow the pipe to slide in them without its buckling or getting out of alignment when there is a strain.

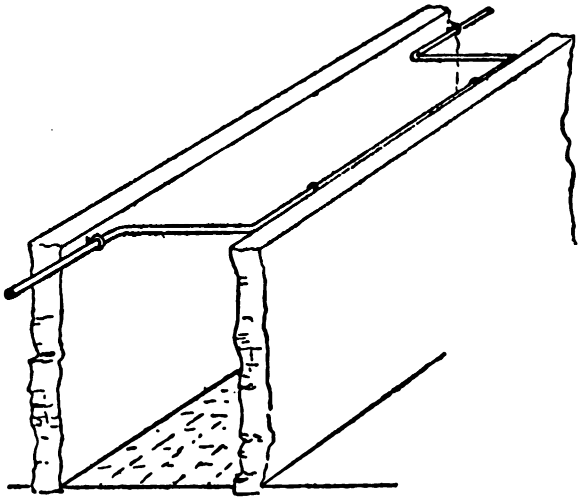

FIG. 11.

Connected on to the steam supply main are the branches or risers to the radiators. These are single pipes, entering one end of the radiator only. The common inclination is to have two connections to the radiator in the same way as a radiator is connected up with the one-pipe system of hot water work; but this is unnecessary and would intr faults, as will be plainly seen later when describing th pipe system of steam heating. There, is, however, a fault in a single pipe connection, about the only fault the system has, for in these branches and risers the steam and condense water have to travel in opposite directions, the steam up, the water down. But it does not prove a fault if care be taken—that is, a proper observation of rules will obviate trouble. Two things must be done to obtain good results, one is to have the pipes large enough to accommodate both the steam and the water, so that they pass without conflict; the other is to give the pipes sufficient rise where they have to travel in a horizontal direction. The rise here should be one inch in five feet or more if possible.

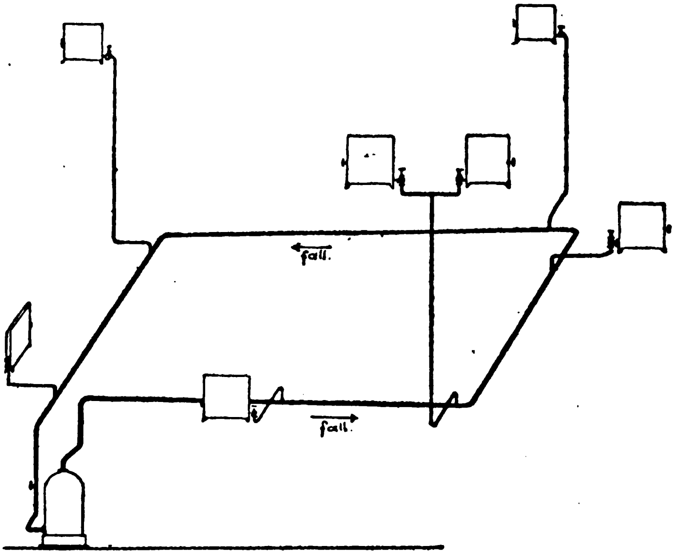

FIG. 12.

In America they have an elbow specially made for radiator branches and risers, called a "pitch-elbow," or "eighth-pitch elbow," which allows of the rise being obtained without setting the pipe, straining the joint, or cutting uneven threads. It will be understood that these remarks apply more to risers than radiator branches, unless the latter be long or have more bends than usual. As the function of a radiator is to dissipate heat, there is necessarily considerable condensation of steam, and it is the water from the radiators that the risers and branches must have running back through them, not only the little that is condensed in the riser itself. The riser or branch has to act as a draining pipe to radiators, as well as a steam supply service.

As previously mentioned, the one-pipe system of steam heating plant proves economical of pipe when the work is

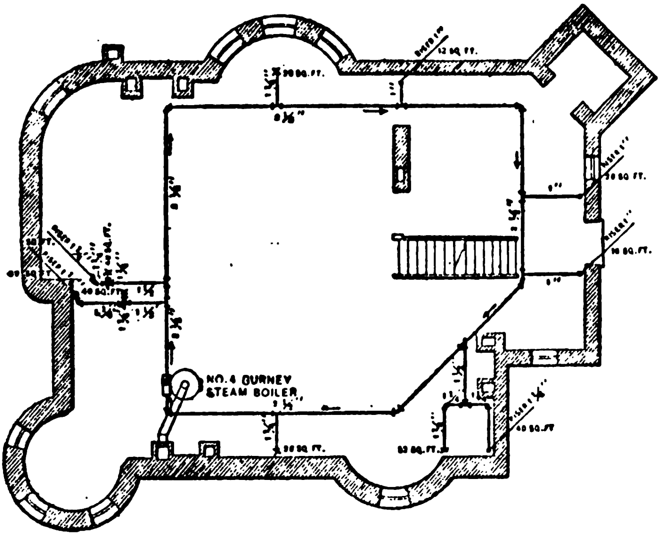

FIG. 13.

more or less scattered, so that the main is carried as a circuit round the basement of the building. Fig. 12 gives a perspective view of the piping in such a case. All the main is practically for steam supply, and the return is limited to the short drop to the boiler. When the work lies in a direct line from the boiler, the supply main has to go straight out to the furthest radiator, and the return consists of an equal length of pipe merely to bring the condense water home to the boiler. As the return pipe is only a kind of necessary evil, it is better if limited to the shortest possible length and expense in

With Fig. 12, the economy is perfect in this respect, as the steam supply, in reaching round to the various radiators, has to come back to the boiler before its work is completed, and it might be said there is no return pipe at all so far as cost is concerned.

Another example of a simple form of apparatus can be given in Figs. 13, 14, and 15. This much resembles Fig. 12, but is not intended to be the same; it, however, gives in plan much of the detail and the general principle embodied in the last example. These three plan drawings were published by the Gurney Heater Co. It will be noticed that the radiator surface, or radiation as it is called, in this example, is very liberal, averaging about 20 super feet per thousand cubic feet of space. This is accounted for by two things: firstly, that it is an American engineer's scheme, and the rule in that country (in the northern states, also in Canada) is to allow for a 65° or commonly 70° rise of temperature. That is, the heating surface is calculated to give 65° or 70° indoors when the thermometer registers zero (32° below freezing point) outside.

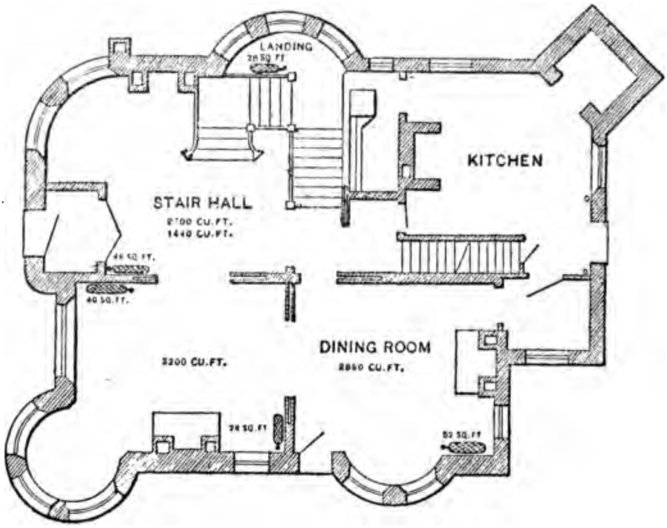

FIG. 14.

In England, we usually calculate on a 36° rise, which is from 26° (6° below freezing) to 62°. It is considered in this country that 62° is a fairly comfortable temperature, something to be satisfied with when it is 26° outside. Occasionally 65° is desired, but this is the highest, and is only an addition of 3°, making the total rise barely more than half that provided by the American engineer. The second reason for a liberal surface in the plans given is that a very full area of window glass is shown, and in heating works of this kind it is the glass that causes the greatest loss of heat of anything used in building construction. It may here be mentioned that for ordinary English living rooms, if heated by steam, 10 feet of surface per thousand cubic feet of space is usually sufficient. This is supposing no fires are lighted in the rooms at any time. If fires are used in the coldest weather, then about 7 feet of steam heated surface per thousand would suffice.

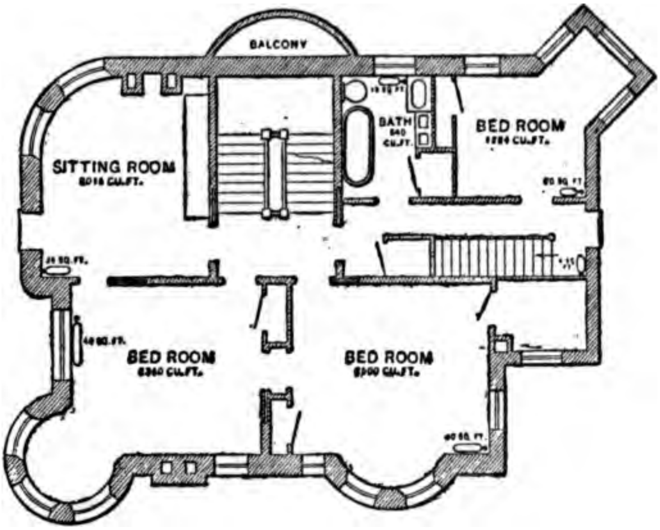

FIG. 15.

An example of residence work on a more elaborate scale is given in Figs. 16, 17, 18, 19, and 20.* This is an American country residence, and it may be mentioned that examples of English residences heated throughout by steam are very rare, or they would be given in preference. There is, however, much to be learnt from American practices, in steam heating work, for they are much more advanced in this than we are.

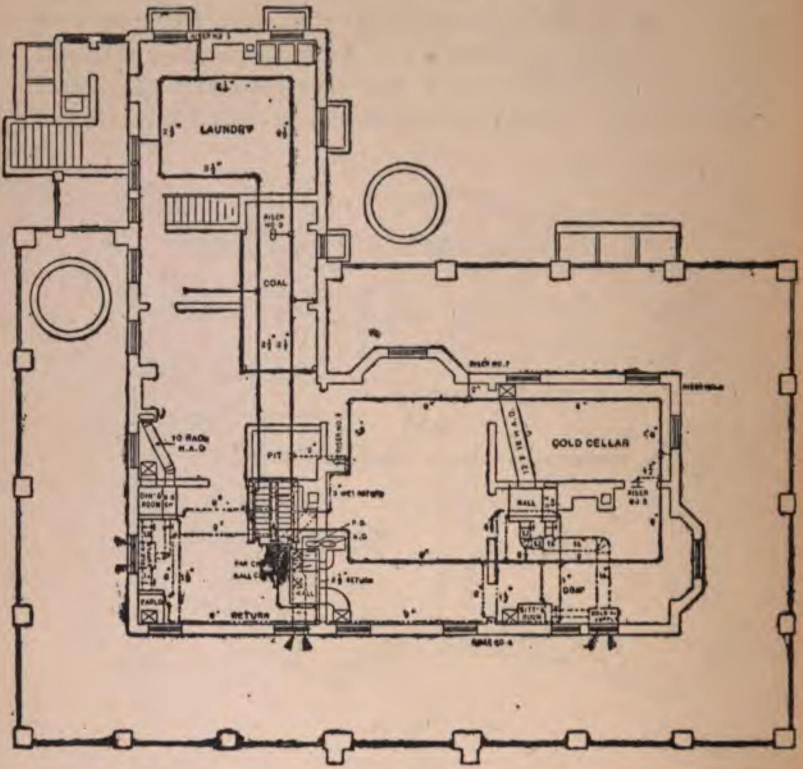

FIG. 16.

This is an example of combined direct and indirect work, "direct" meaning visible radiators, and "indirect" meaning radiators out of sight and having their warmth brought into the rooms by an air-duct.

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* From 'Heating and Ventilation.'

The basement plan shows the location of the heater and indirect stacks, cold air supply, size and run of pipe system; and the riser plan, Fig. 20, gives the sizes of the several risers, which are run as follows:

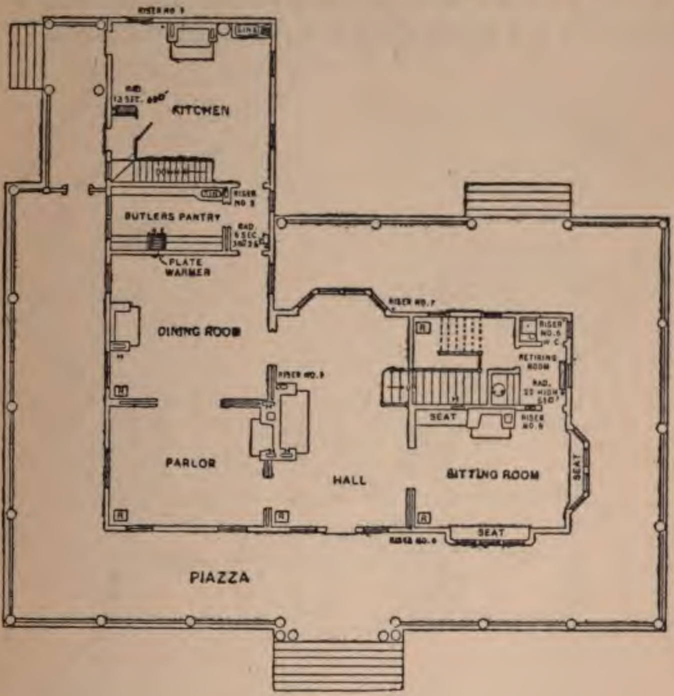

FIG. 17.

No. 1, just to the left of the heater, runs through an old hot air pipe to the second floor, where it supplies radiators for middle hall, bath room, and sink room, thence through bath room to third floor, where it supplies radiator in middle hall and bath room.

No. 2 runs through hot air flue to second floor, where it supplies radiator in chamber over pantry and rear hall, thence to third floor, where it supplies rear hall radiator.

No. 3 runs through kitchen to the chamber over it, being the only exposed riser on the first floor, except riser No. 6, which is used as radiation in water closet off the retiring room to protect the plumbing.

No. 4 runs through partition behind the double door between hall and sitting room to water closet, on second floor, whence it acts as a radiator, thence to third floor, where it supplies radiator in front bed room.

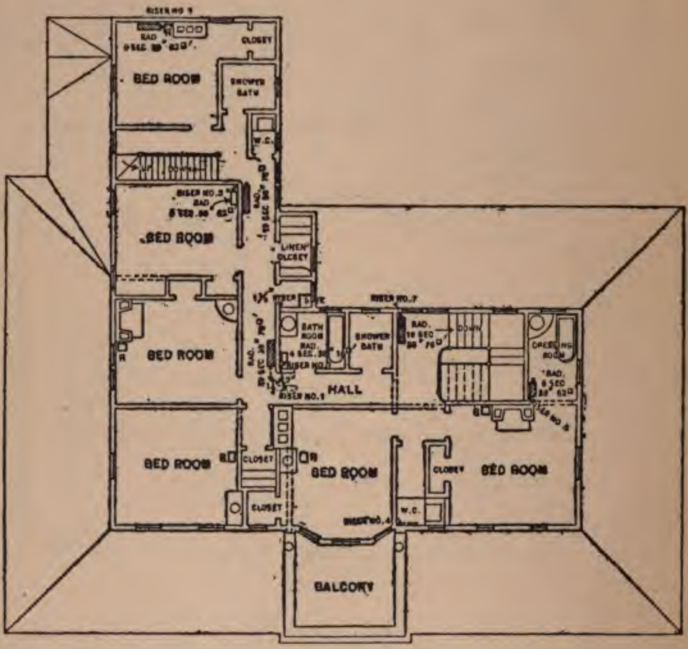

FIG. 18.

No. 5 runs through hot air flue to supply the dressing room radiator in second floor front hall. The riser is well covered, and then boxed to match the outer wood work.

The apparatus is capable of heating the entire house to 70° F. in coldest weather, with less than one pound pressure at the gauge; is absolutely noiseless and positive in its operation, and consumes very much less fuel than the hot air furnaces which it replaced.

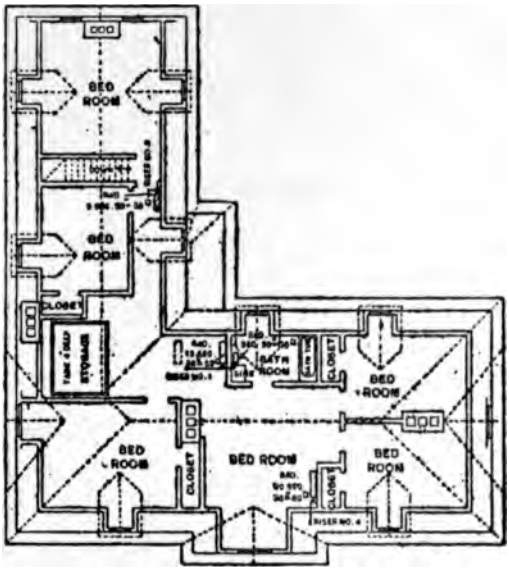

FIG. 19.

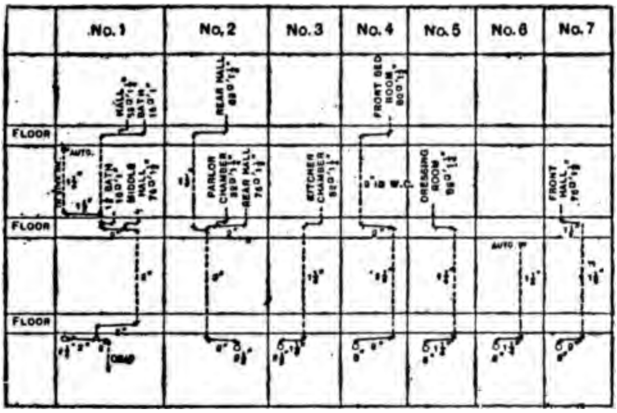

FIG. 20.—RISER PLAN.

The following is a list and description of the radiators. It will be found that the surfaces are much more liberal than are needed in England, as explained on page 48.

Rooms.	No. of Radiators.	Style.	Height.	Square feet of Direct.	Square feet of Indirect.
FIRST FLOOR.					
			Inches		
Hall	2	Indirect	..	..	276
Sitting room . . .	1	„	..	..	96
Retiring room . .	1	Direct	22	51	..
Water-closet . .	1	Riser	..	4	..
Parlour . . .	1	Indirect	..	..	108
Dining room . .	1	„	..	..	108
Pantry	1	Plate warmer	..	15	..
Passage . . .	1	Direct	38	25	..
Kitchen . . .	1	„	38	65	..
SECOND FLOOR.					
Over					
Sitting room . .	1	Indirect	..	..	48
Front hall . . .	1	„	..	..	48
Parlour . . .	1	„	..	..	48
Dining room . .	1	„	..	..	48
Pantry	1	Direct	38	32	..
Kitchen . . .	1	„	38	32	..
Dressing room . .	1	„	38	32	..
Bath room . . .	1	„	38	16	..
Water-closet . . .	1	Riser	..	6	..
Halls	3	Direct	38	228	..
Sink room . . .	1	Riser	..	4	..

Rooms.	No. of Radiators.	Style.	Height	Square feet of Direct.	Square feet of Indirect.
		THIRD FLOOR.			
Front bed rooms . .	1	Direct	38	80	..
Bath room . . .	1	”	38	16	..
Middle hall . . .	1	”	38	32	..
Rear hall . . .	1	”	38	35	..
Totals .	27	..	..	693	780

Summary.

Making in all 14 direct radiators, 9 indirect radiators, 3 exposed risers, and 1 plate warmer coil.

There are occasions when it is thought desirable to have a separate return or condense water main to this one-pipe system of apparatus. This would be when the risers are of considerable height, each one supplying a large total area of radiation and having a proportionately large volume of condense water coming down it. By providing a separate condense water main, this quantity of water need not come back into the steam supply main, and the likelihood of noise or trouble will be minimised or obviated. This is the argument in favour of the condense water main, but on the other hand, the risk of conflict between the steam and water in a single main can be obviated by having it of sufficient size.

It must be acknowledged that if there is a water-hammer at all it is more likely to be in the horizontal pipes than in those that run vertically; hence an arrangement embracing two-pipe horizontal mains with one-pipe risers is more promising of noiselessness than the ordinary one-pipe arrangement, assuming that the risers are carrying a large area of radiation.

If a two-pipe main is decided on the return should be "wet" or "submerged," that is below water line. In two-pipe work it is so essentially an important detail in securing noiselessness and efficacy (as will be found fully explained a little further on), and it should be considered as essential in this case.

The reason for mentioning this so pointedly is that engineers have considered an overhead return sufficient for this purpose, as Fig. 21. This sketch shows two sets of riser connections in perspective, closer together than they would usually be, but drawn so that that the fault may be more easily seen. It will be noticed that the return connection of one riser provides a bye-pass for steam to the next return connection, with the result that steam will have access to, say, the second riser from two directions. This is indicated by the arrows which show movement of steam only and not condense water.

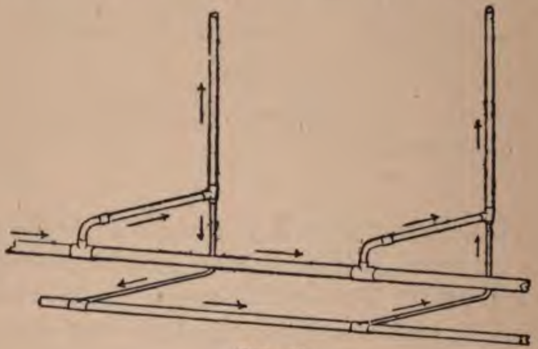

FIG. 21.

Such connections are a prolific source of erratic results and noise. Steam coming to one point from two directions will frequently prevent either supply doing work, and worse than this it will most effectually interfere with the placid flow of the escaping condense water. Bye-passes in steam work are a real evil and must by every means be avoided. An ordinary single pipe main would give decidedly better results than a two-pipe arrangement connected as just shown.

The return must be below water line as Fig. 22, and this effectually seals the bye-pass. The return is then "wet" or "submerged" as previously stated. It will be noticed that the riser connection from the steam supply main is made to fall in this case, as this secures the draining of the riser into its "relief" or "drip," which goes down to the return. An even better way for the steam connection is to make the tee look downwards, as Fig. 23. This ensures not only the certain draining of the riser to the return, but each connection takes the condense from the steam main itself and keeps it dry. The relief or drip need only be a small pipe, and a table of sizes of these will be found with the description of the two-pipe system.

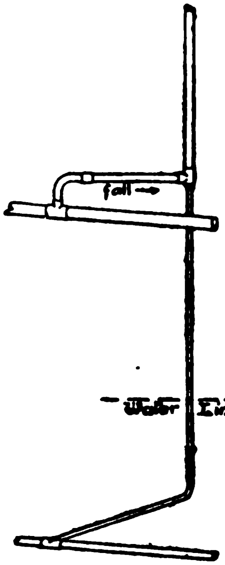

FIG. 22.

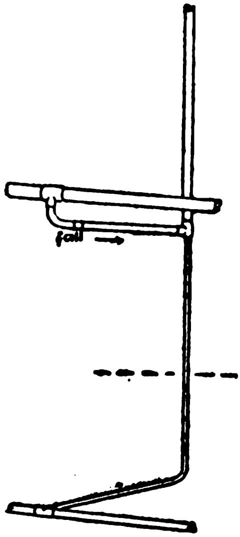

FIG. 23.

The sizes of main pipes of this one-pipe system with duplicate mains will be the same as the two-pipe system, which is next described. This is so far as the mains are concerned. The risers will remain the same sizes as recently given for the ordinary one-pipe apparatus.

As opposed to the argument that a condense water main is needed with a large one-pipe apparatus, the example embodied in Figs. 24 and 25* is given. This is the steam-heat-

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* From 'Heating and Ventilation.'

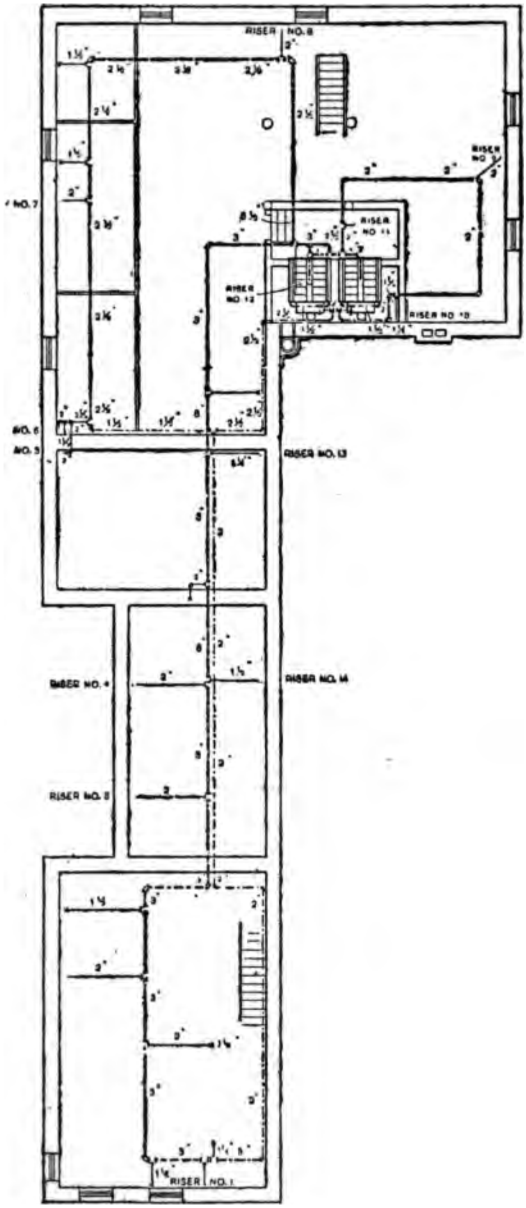

RISER NO. 8
RISER NO. 9
RISER NO. 11
RISER NO. 12
RISER NO. 10
NO. 7
NO. 6
NO. 5
RISER NO. 13
RISER NO. 4
RISER NO. 14
RISER NO. 2
RISER NO. 1

FIG. 24.

ing plant of an hotel of four floors, the riser plan of which will show that the scheme is of fair magnitude. This apparatus is said to be working perfectly and without noise.

A detail that every steam-heating engineer has to become acquainted with at some time or other is what is known as a "relay." In the simple examples given there are no obstacles to pass, and the length of pipe is such that the needed fall can be obtained all the way without coming too low to pass over doorways, etc. Supposing, however, an obstacle is met with, or the run of pipe is such that its gradual fall brings it inconveniently low, then recourse must be had to jumping the main up again, and this makes a dip or pocket in the run. This dip will form a very perfect collecting place for condense water, and unless drained would stop the proper working of the apparatus in very quick time. The travelling ste
might clear the way now and again, but it would be a tro
some process with very erratic results and much noise.

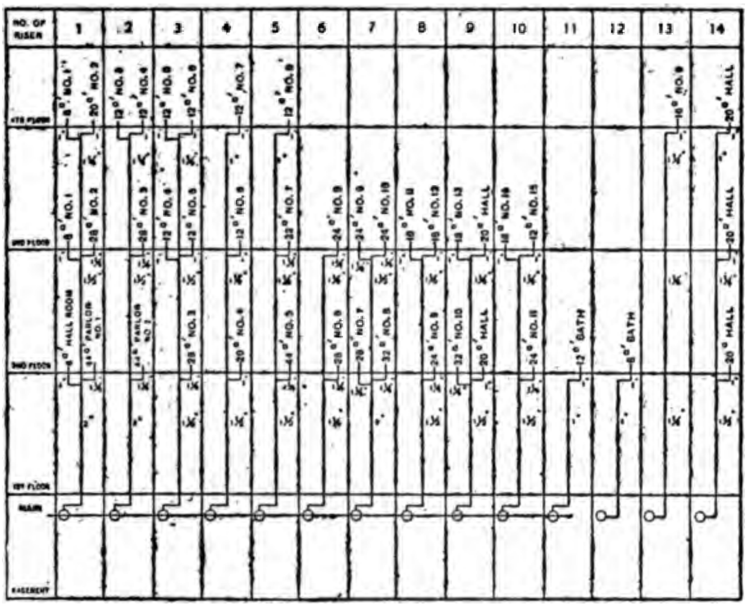


FIG. 25.—RISER PLAN.

Fig. 26 shows how this dip is drained, a small pipe being returned to boiler from this point. As the jumping up of the main is called a "relay," its draining pipe is called a "relay relief," though quite often it is called a "drip" or "drip pipe." These latter expressions are often used to indicate any pipe which independently takes the condense water from one particular point, such as that shown, or from a long riser, or from the foot of a vertical steam supply main.

The choice of valves is a detail of importance in steam work, particularly in seeing that they will not pocket water, or cause water to be pocketed on either side of them. The old form of screwdown valve (not an angle valve) has what may be described as an up and down way through it, quite impeding the return flow of condense water unless the valve is fixed on its side. Even then the way through is seriously crooked and also restricted, a 1 inch valve not having nearly a 1 inch area or way through it. If valves are used in horizontal pipes then they must be gate valves—Peet's valves they are commonly called. These have a full and clear straight way through them. The angle valve, as now generally used for connecting up radiators, is quite good for this work, but if any packing or washers are used in it they must be of a kind to withstand steam heat and be suited generally.

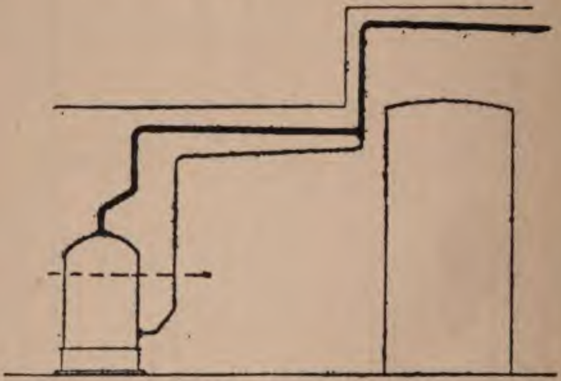


FIG. 26.

What is much wanted is a valve that can be opened and shut quickly, like the "Detroit" valve (which is unsuited for steam), for as a steam valve cannot be partially closed at all satisfactorily, it is well to have one that can be opened and shut with reasonable expedition. The reason a valve cannot be partially opened or closed is that in partially shutting off the steam supply the exit of the return water from the radiator is also checked. It practically amounts to giving the radiator too small a branch pipe for the time being, and the consequence is that the steam and condense water come into conflict. The radiator valves must be full open or tight shut, which is really a drawback to this system of heating, there being but little means of regulating the heat given off by the radiators.

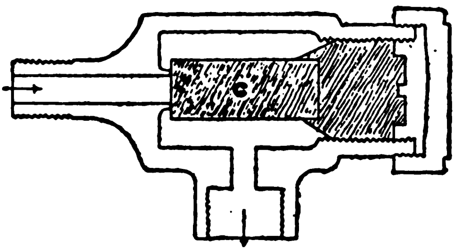


FIG. 27.

All radiators have to be provided with air vents. These can be cocks to be opened by hand or automatic. The former are seldom used, and automatics have everything in their favour, especially as reliable makes can be had. Automatic air vents for hot water works have as yet proved disappointing, and few make use of them, but the reverse applies with vents for steam work.

Most auto-vents are made on the principle of Fig. 27, which shows Jenkins' valve in section. This consists of a brass case with screw cap at one end, and inside it has a screw plug carrying a cylindrical piece of composition, marked C. This composition is the working part of the device, and is very commonly called the "pencil." The end of the case with the small aperture is the part that screws into the radiator, while the large aperture is the air outlet. The composition pencil is a material which expands rapidly and considerably with heat with a corresponding degree of contraction when cool.

As shown in the illustration the pencil is expanded and the vent closed, which indicates that all air is out and the pencil is hot and expanded, due to steam heat. When steam is let down the pencil will contract and draw away from the radiator opening and allow air to pass in; so that not only does the vent admit of air expulsion when steam comes up, but it also admits of air entering when steam is down and a vacuum about to be made in the apparatus. It is an aspirator which, at different times, has air passing through it each way in the performance of its duty. While the radiator is cold, or at any time that air is next to the vent, the pencil is contracted and leaves a free opening; but when the air is expelled and steam follows, the expansion of the pencil and the closing of the opening occur promptly.

This vent has provision for attaching a small drip cup, an ingenious adjunct to the outlet orifice. When steam follows the air expelled from a radiator the opening does not close so instantaneously as to prevent a slight issue of steam, and probably a drop of water hanging on or falling from the orifice. The drop or two of water falls into the little cup, and this being hot, by its immediate connection with and proximity to the radiator, the water is quickly dried up. The drip is therefore disposed of very satisfactorily instead of falling on to the floor.

Air vents are placed on every radiator, but the position is not the same as with hot water work. Steam is lighter than air, and theoretically the air vent should be at the bottom of the radiator. This would be the correct place practically, if the steam entered the top of the radiator, but as this is not done and the steam supply comes in at the bottom, a point is chosen for the air vent which will act best after allowing for the fact that the steam and air mix to some degree when they come together in this manner. It will be noticed in previous illustrations that the air vents on radiators are on the ends furthest from the steam supply connection, and this is correct on whatever system the apparatus be erected. It is placed not quite half-way up the end section, not near the bottom nor the top, but just about the distance shown in the drawing, that is, not quite in the centre and nearer the bottom than the top.

An air vent is also marked on the return pipe just above the water line of the boiler. This is always desirable and commonly necessary. When the return is a considerable length of pipe it needs an air vent as much as a radiator. The steam supply main has vents in the radiators on it, but the return has no such relief, and it is well to provide it with a vent even when moderately short in length.

The sizes of pipes for one-pipe steam work are larger than for two-pipe, the latter having separate pipes for the steam and the condense water at all points. The one-pipe has to carry both in the one pipe, and in the branches and risers they travel in opposite directions and must not quarrel.

The sizes of mains here given should not be reduced. If there is doubt use the size larger. It is a safe plan and proves highly satisfactory. It is understood that low-pressure steam is used, this being steam at 2 to 6 lbs., or perhaps 8 lbs. pressure on the gauge. With higher pressures the pipes may be smaller.

Amount of radiation. This includes mains, risers, and branches, unless these are well covered and scarcely lose any heat.	Size of main pipe.
Up to 200 square feet	1½ inches.
200 „ 400 „	2 „
400 „ 650 „	2½ „
650 „ 900 „	3 „
900 „ 1250 „	3½ „
1250 „ 1600 „	4 „

The rule this table is based on is the generally accepted one that the area of a 1 inch pipe (·7858 square inch) must be allowed, in mains, for each hundred square feet of radiating or heat losing surface. The figures are also based on the assumption that the mains (and the branches) are of reasonable length for the amount of radiation. The first size, 1½ inch, is considered the smallest size for a main pipe even if it only 100 feet on it.

For the branches and risers the pipe area is greater as follows:—

For less than 25 square feet of radiation	1 inch.
25 to 60	1¼ "
60 " 100	1½ "
Above 100	2 "

It will thus be seen that with a small apparatus it would be quite possible to have a 2-inch branch or riser on a 1½-inch main, though the occasion for it may be unusual.

A good rule is to use even one size larger pipe in the branch or riser just where it joins the main—that is, the tee outlet and a few inches of pipe—for it is here that the commotion arises, if any, between the upgoing steam and the returning water.

The Two-pipe System.—Opinion is divided to a certain degree, amongst engineers who practise steam heating, as to the superiority of the two-pipe over the one-pipe system. As already pointed out, the one-pipe is cheaper; it is also more simple generally; and, with no more than ordinary care, it can be made practically noiseless in working, except that in some cases it is difficult to prevent a few manifestations when steam is first got up, everything cold, and condensation makes its maximum volume of water in the pipes. It is doubtful if very many two-pipe apparatus exist that are absolutely quiet at this time. In the hands of a fitter who has had but moderate experience there is a greater likelihood of error in construction with two-pipe work, but this, as in everything else, depends on the care exercised and the man's capacity for seeing the purposes of the constructional parts.

A two-pipe apparatus is constructed with the view to keeping the steam and condense water quite separate as far as possible, particularly the water that comes from the radiators, where the most water is intended to be made. The radiators therefore have a flow and return, a steam supply and a condense water service, connected one at each end. It may be peated that the object of this precaution is to prevent the am and water coming into conflict, which not only causes noises which no one is willing to bear, but also prevents the radiators heating, besides introducing faults in other parts of the apparatus, even at the water-line in the boiler.

Fig. 28 gives the elementary principles of a two-pipe apparatus, in which it will be seen that a flow or supply main is taken from the boiler and a return back to it, much as described with the one-pipe system. The supply main rises to its highest point at once and then falls all the way, so that the steam and whatever condense water is in this pipe travel together and not in opposite directions.

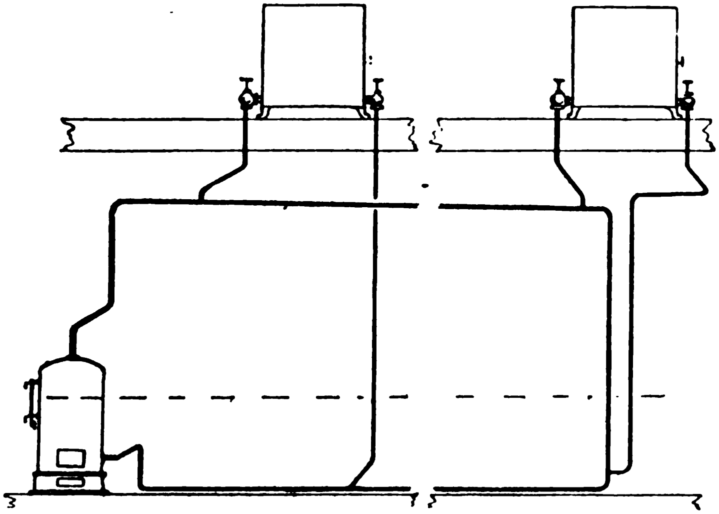


FIG. 28.

There is a difference in the position of the main return, as this requires to be below the water level of the boiler; this is the "submerged" or "wet" return. The illustration shows this at floor level, but it can be a few inches above this if it is to run along a wall; or, as is more usual, it is run just below the floor, either in a trench or covered up. It is best to keep it well below the water-line.

From the supply main branches are shown taken to radiators, or there can be risers, as will be described dire
These radiator branches are taken with the customary

(already explained) and are connected with a stop cock in the usual way. In this short length of pipe there may be a little condense water coming back in a contrary direction to the steam, but as the pipe does not carry the condense water of the radiator it can be a smaller tube than with the one-pipe system, as the table of sizes will presently show. When radiator branches are taken from risers it is best, if possible, to give the branch a fall, so that whatever condense water it may make will go, with the steam, into the radiator, to be disposed of from there by the return service provided. There is no occasion to run water back into the supply main, however little it may be, if it can be avoided.

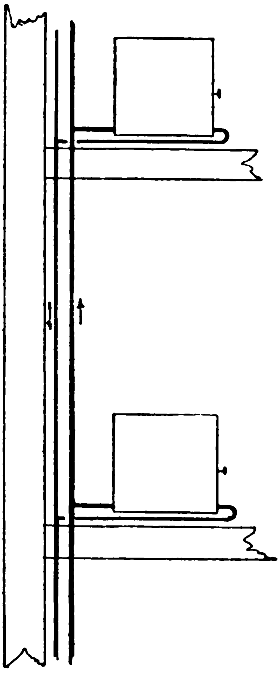


FIG. 29.

From each radiator is taken a return, as shown, and this has to be provided with a stop cock also. The two cocks have to be opened full or shut simultaneously, otherwise erratic results must follow. If the return valve is open when the steam valve is shut, then the return water will back up, and more or less fill the radiator. It is practically impossible to regulate the steam supply to the radiator; the valves have to be full open or quite closed.

The return from the radiator, it will be seen, is taken down to the main return, the connection being below water-line. If it could be returned anywhere above water-line there would be trouble, more so than would be obtained with any one-pipe apparatus. Such a connection admits of steam getting at a radiator from two directions, as will be shown directly, and unless the flow of steam be from one direction only there can be no certainty of results. It is also wrong to admit of steam traversing the return pipe in any direction it pleases, interfering with the flow of condense water, and probably preventing the proper discharge of air.

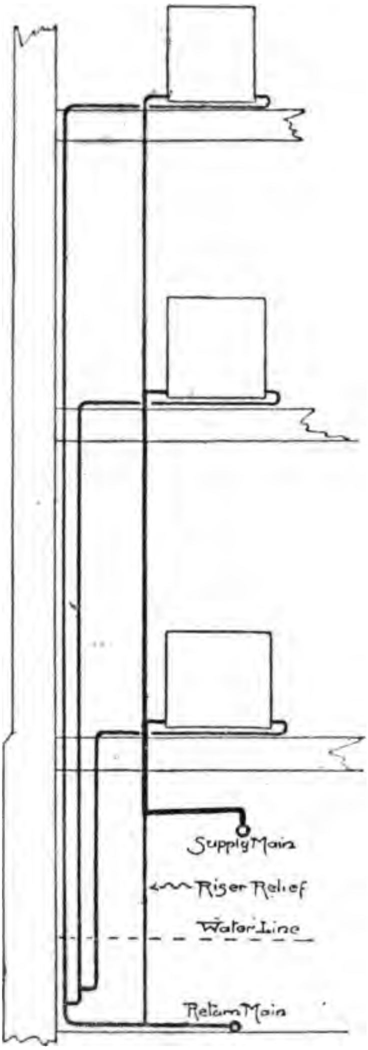


FIG. 30.

The illustration, Fig. 28, shows radiators on the floor above the basement only, but if there are other floors above to be heated, then risers must be provided, and the radiators connected to these. If they were connected up as Fig. 29, which is obviously a hot water apparatus connection, the fault just explained would be experienced, but notwithstanding this it is no uncommon thing for steam radiators to be found so connected. It will be seen that the steam entering a radiator, and which is not wholly condensed there, passes into the return, and from here it has direct communication with other radiators, above and below it, by their respective return connections. To have steam entering a radiator (or endeavouring to) at both ends, must result in irregularities. It may be that the condense water will be held up in the radiator; or it is not impossible to have, at certain points in an apparatus, a trifle higher pressure in the return than in the supply, assuming that the steam can get freely into the return;

but the apparatus would then be a pronounced failure, and without doubt very noisy.

The correct way of dealing with radiators in their relation to risers is as Fig. 30. In this it will be seen that the steam supply riser is utilised to furnish steam to all the radiators by means of the short branches shown. The returns from the radiators, however, have no communication with one another whatever until they are below the boiler water line. Each radiator has its own distinct return, and this is where a considerable expense is incurred. The steam supply riser is not so large a pipe as with the one-pipe system, and the separate radiator returns are quite small pipes, so that the outlay in material is not abnormally great, but the labour is distinctly greater, as will be seen.

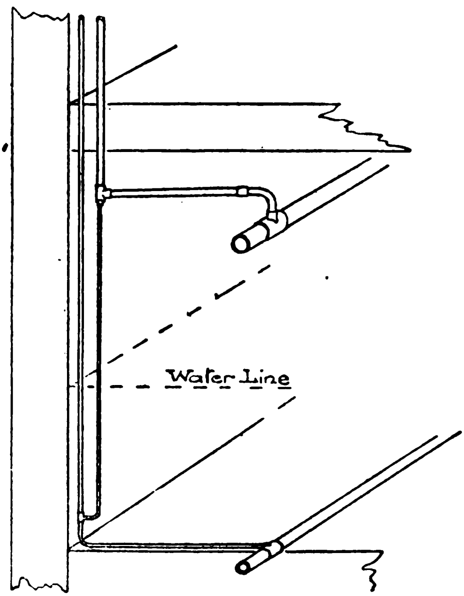


FIG. 31.

The returns are shown connected into one another. This is to save expense, as a small tee can thus be used. If they enter the main return it costs more for fittings. Again, if the pipes come down in a bunch as they would do, it is much more convenient to connect one into the other than to have a row of tees in the main return.

A detail is given in this sketch which has not yet been referred to—this is the "relief" or "drip" pipe at the foot of the steam supply riser. This would be a particularly desirable detail in a one-pipe apparatus, but as there is no wet return to this latter system, there is no place to take the "relief" into, unless it were taken back to the boiler. With a one-pipe job this relief would relieve (as its name implies) the supply main of the water that comes down from the radiators. In this two-pipe apparatus it takes whatever water the riser itself is accountable for, and keeps the supply main as dry as possible. It will be seen that the riser falls immediately it leaves the main, but this would not be possible if the relief did not exist. The sizes of these pipes will be the subject of a table later.

In Fig. 31 are given the details of the connections from the mains, in perspective, but only showing one radiator return. The mains do not come directly under the riser, and are best kept some two or three feet away. This entails using more fittings than if the riser went straight up, but it is essential that a connection, such as is illustrated, be used, to allow for the push and pull of the mains as they expand and contract. The main return is here shown on the floor, but it can be a few inches up the wall if desired, or under the floor, either covered or in a channel.

At the extremity of the steam supply main the pipe has, of course, to drop to the floor to come back as the return. This drop pipe, although part of the supply or return main, whichever way it is taken, is given a distinct name. It is known as the "main relief" pipe, and its purpose is to take whatever water there is in the supply main and deliver it into the main return. In a hot water apparatus this piece of vertical pipe would be considered as the beginning of the return pipe, but in this work it is considered as a pipe that drains the steam main only ; and it need only be a small pipe.

Simple as this pipe seems to be, it is quite possible to get bad results if one attempts to make it fulfil two purposes, as is often done. The steam supply is only carried as far as the furthest radiator or riser, and then drops to the floor, and it is proposed to make the main relief and the radiator return one pipe as Fig. 32. This would give bad results, as it amounts to putting both the radiator connections on to the supply main. The connection must be made as Fig. 33, the details of which speak for themselves.

It may become necessary to dip, or to jump up, the steam main of a two-pipe job, the same as explained with the one-pipe system, and this "relay" is made in precisely the same way as already explained. It is, however, much easier to drain it, as its relief or drip pipe has only to come down to the wet return, which is presumably just underneath. Fig. 34 illustrates this.

Air valves are needed on all the radiators in just the same manner as previously explained. It is also desirable to put one in the "main relief" (the drop pipe connecting the two mains at their extremities) just above the water-line. This was previously explained with the one-pipe system.

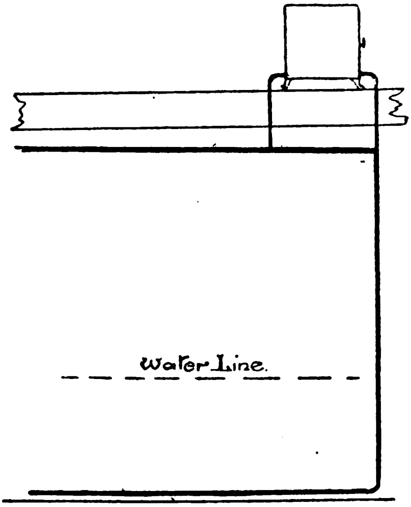


FIG. 32.

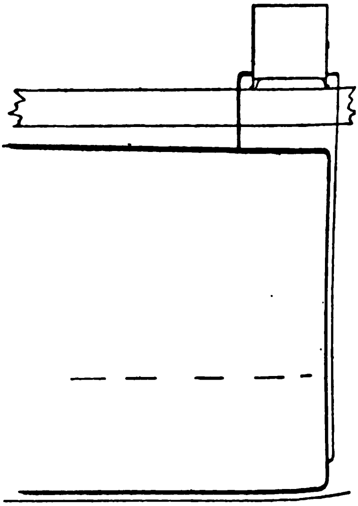


FIG. 33.

It has been explained how necessary it is with a two-pipe system of apparatus to have the radiator returns terminating below water-line, so that there is no chance of steam coming up them. It will not do to have steam coming to a radiator from two directions. In special instances, however, where a radiator cannot have its return carried down to the main return, it is permissible to make a false water-line by connecting the return of this radiator to the return of another one, or to any dry return, in the manner shown at Fig. 35. In other words, a dip in the return under treatment, just before it joins the other return, pockets sufficient water to prevent the steam of one return pipe entering the other either way. It is not a reliable practice, though, and must be considered as a means to meet special conditions only.

It will be noticed that to have a wet return, in the usual way, necessitates the boiler being set on the floor of a basement which extends under the whole or greater part of the building. If there is no basement, or if it is of a very limited extent, it would appear as if this type of steam apparatus would be impossible, as a boiler placed in a pit, or single basement room, could not have a return pipe extending any distance below water level, but must have this pipe somewhere about the same level as the steam supply main. It must be an overhead return in its relation to the boiler level.

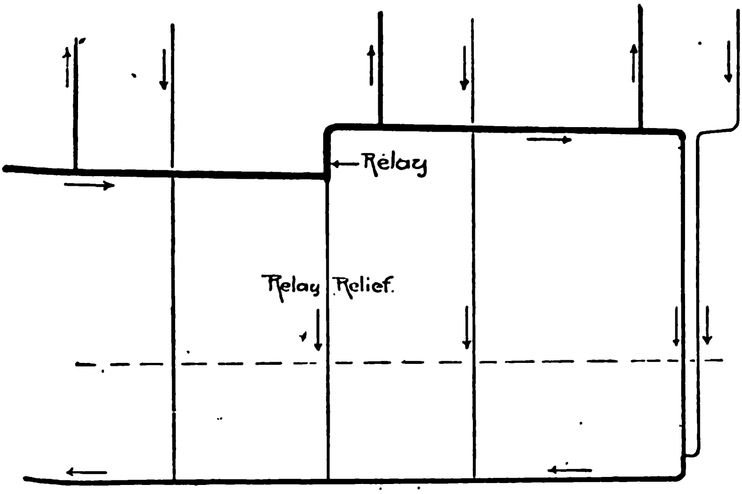


FIG. 34.

It is, however, still possible to make it a wet return by arranging that it provides for a false water-line. This is done at Fig. 36. In this it will be seen that the supply main is carried along with a fall in the usual way, and the return comes back a little below it. After the return, on its way back, has passed the last radiator return it jumps up, as shown, so that almost the whole of the return is one long dip, and pockets water. The returns from the radiators can then be connected into a wet return, as also can the relief or drip pipes from the risers or other points.

An important detail in this plan of piping is the bye-pass or communicating pipe that connects the high part of the main return with the steam main just above it. This piece is called the "equalising pipe," and its purpose is to prevent the water in the return being syphoned over to the boiler. The function of the artificial water line and the necessity of the equalising pipe have been clearly described as follows:—

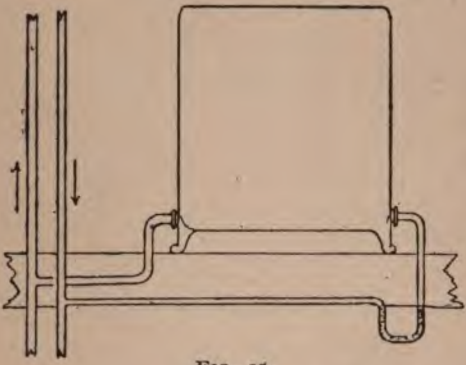


FIG. 35.

"To understand the function of an artificial water line it is necessary first to know what is the effect of the ordinary water line in a two-pipe system of steam heating. In such a system the return risers (radiator returns) are all water-sealed at the bottom, the water rising in them to a level practically the same as that in the boiler when the pressure is equally distributed throughout the system by the proper proportioning of the piping and the employment of suitable relief pipes. This being the case the flow of steam is always in the same direction as that of the condense water from coils and radiators toward, into, and through the returns, being aided and facilitated by the steam flow instead of being retarded or obstructed, as it will be whenever the steam moves in an opposite direction to that of the water of condensation. The freer both the flow of steam and the flow of water can be made the less noise will be caused by the circulation, the more perfectly the radiators will do their work, and the less fluctuation and disturbance of the water-level in the boiler and returns will occur.

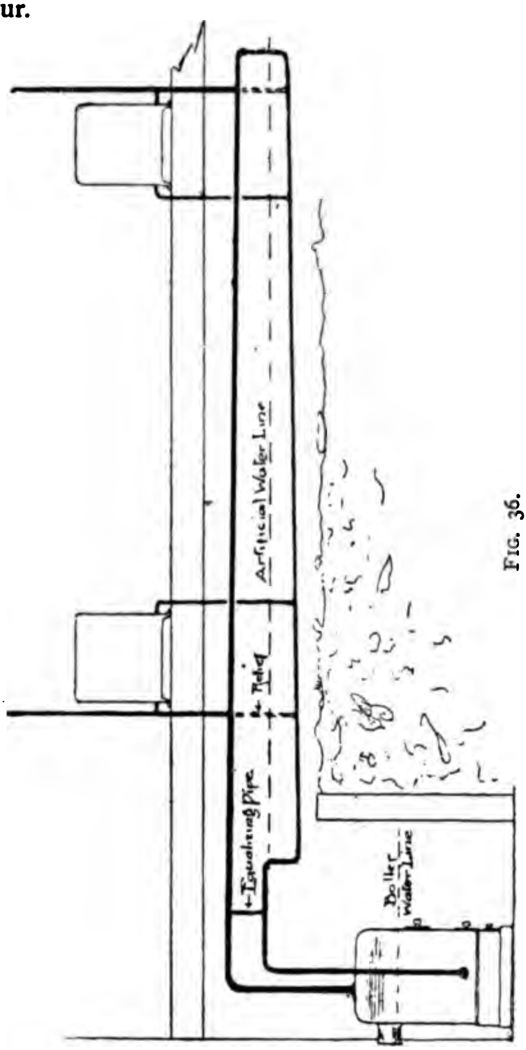


FIG. 36.

Method of obtaining an artificial water-line, that is, a water-line above that in the boiler. By this means a "wet" or "submerged" return can be had without going down to the level of the boiler pit, supposing the pit is below the basement or lowest floor.

"In a two-pipe system it is sometimes impracticable or undesirable to place the return main at or near the level of the bottom of the boiler, and it must then be carried above the boiler water-line. If this is done without using an artificial water line it requires only a little thought to perceive that the steam passing through a radiator will flow directly on into the return main. Once there it will attempt entrance to other radiators through their outlets, and will do this at the same time that steam from the supply main will be entering in the regular way. The water of condensation will therefore be entrapped between two currents of steam, each of which tends to drive the water in a different direction. The consequence will be that the water will be driven first one way and then the other in the radiator, making a water hammer and setting up a disagreeable pounding. With a well arranged artificial water-line the steam will enter the radiators through the proper route only, and the water will flow out of the return connection without hindrance.

"Now, as regards the equalising pipe and the purpose it fulfils, let it be considered what would happen if this pipe were omitted. If it were not there the pressure of the steam in the supply main from the boiler would not be exerted upon the water in the artificial-water line except at the foot of the main relief at the end. The water in the vertical part of the return main near the boiler will lift sufficiently for its weight to counterbalance the water column in the boiler with the steam pressure added, a partial vacuum existing between the elbow where the artificial water-line is connected with the vertical return and the top of the water in this vertical return. If a pressure of two pounds by the gauge is carried in the boiler a rise of a little over four feet in the vertical return will counterbalance this. Under these conditions there would be no back pressure against the water in the artificial water-line at the end nearest the boiler, while there would be full steam pressure on the further end of the water-line through the main relief. By a slight difference of pressure the water in the artificial water-line would then be forced over into the vertical return, outbalancing the steam pressure in the boiler and flooding the latter.

"This forcing over, or syphoning, as it is often called, cannot occur if the equalising pipe be employed, because, by its use, the steam pressure is made equal on both ends of the water-line, and the water then lies quietly in it. There is no unequal force to give it a tendency to move in either direction, and the only water passing over into the return to boiler is the condense water that comes down from the radiators. The water of the artificial line, it may be noted, is condense water and there is no occasion to fill it specially when first starting. It fills itself when the apparatus is first set going, but it is necessary at this time to add water to the boiler, as this line may take sufficient to lower the water level of the boiler considerably when it is first filled."

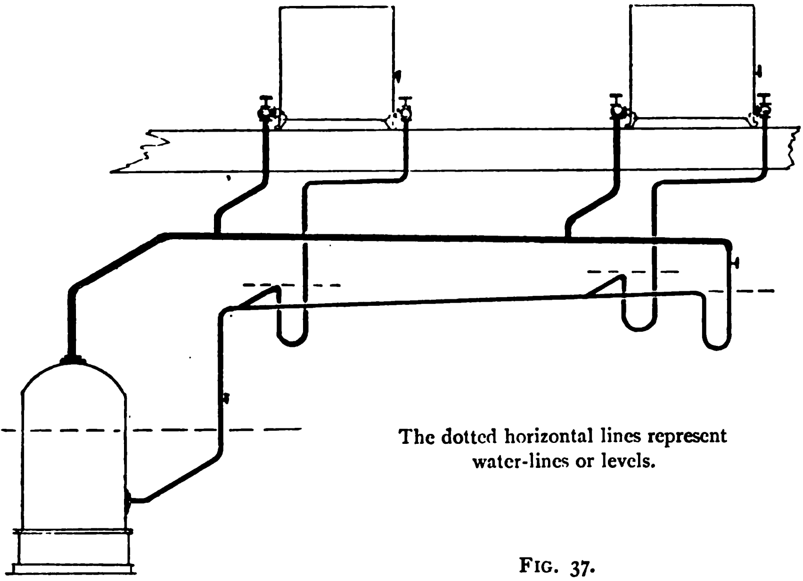
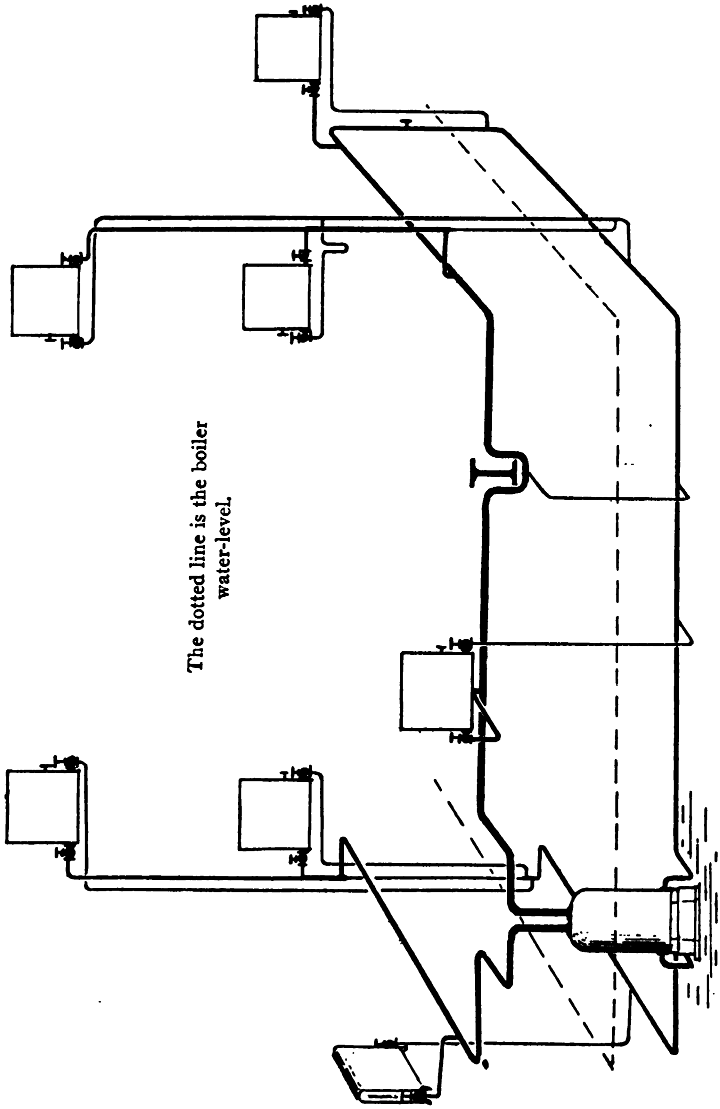

The dotted horizontal lines represent water-lines or levels.

FIG. 37.

This latter applies also to any system of apparatus which has a wet return, a return holding water.

A modification of this arrangement is to dip each return pipe, also to dip the main relief, as Fig. 37, this arrangement providing for the artificial water-line in each independently, thus leaving a dry main return. This will act successfully if the bottom of syphons be deep enough. A dip of one foot gives a boiler [illegible] column which has a pressure of nearly half a pound per [illegible] square inch. A dip of 2 feet 4 inches is equal to one pound



The dotted line is the boiler water-level.

FIG. 38.

pressure per square inch. If the pressure in a steam heating apparatus was equal everywhere a small dip would suffice to seal the returns, but as the pressure in flow and return may be a little unequal at the distant parts of a piping system, there is the risk of the dips having their water forced out. An equalising pipe is wanted.

These dips, also the recognised artificial water-line, and the ordinary wet return, should have some provision made to empty the water out if there is the likelihood of the apparatus being left out of use for two or three days during a hard frost. A small emptying cock, or even an air cock, will discharge the water if placed at the lowest points.

A perspective view of an ordinary type of two-pipe apparatus is given in Fig. 38, this example being made up to include most of the details that appear in work of this kind in moderate size. It is probable that a system of piping such as here given would carry more radiation than shown; but this is a detail that need not be gone into, for there is no rule as to the amount of radiation to a given length of pipe—in fact it varies to such an extent that probably no two apparatus are alike. As the length of pipe increases so must its diameter, for given results, and this will be found referred to under the table of sizes of mains, etc.

When the radiators are down near the level of the water-line in the boiler (and they may sometimes be found within 24 inches of this), a pound pressure more on the water than on the steam side will back the water up into the radiators. It is not an uncommon thing for a greater difference than this to exist between the pressure in a boiler and the pressure at the bottom of returns remote from the boiler. Under these conditions water will stand higher in the distant returns than it does in the boiler, and it may be high enough to flood radiators, or partially so.

To obviate this as much as possible, a check valve is used in the main return, near the boiler, and it is the rule whether the apparatus be well proportioned and arranged or not, to put a check valve unless the apparatus is of quite a small character. The ordinary form of check valve for this work is as Fig. 39. Its flap is not so sensitively hung as with the valve used in hot water circulations. By putting in this valve, the effects of unequal pressure are in a large measure prevented. Boilers, too, when forced, are inclined to back water out of them if no check valve is provided. There is no doubt that a check valve is unnecessary except to obviate the results of faults or bad attention, and it would be possible to erect an apparatus in which a check valve would have no active use. This, however, does not make the valve undesirable, and it is best to provide it in any case if the apparatus is at all extensive.

The description just given relates wholly to the gravity two-pipe system, with submerged return—the system in which any steam passing through a radiator and entering a return service has no opportunity of reaching other radiator services. This entails the utmost outlay that can be made on account of the many return services, and in business premises, where competition work will probably enter, and a little noise not be objected to, a modified two-pipe system may be erected. This is supposing a one-pipe apparatus is not decided upon, which, in the writer's opinion, is decidedly better than any economical form of two-pipe work, if it is possible to use it.

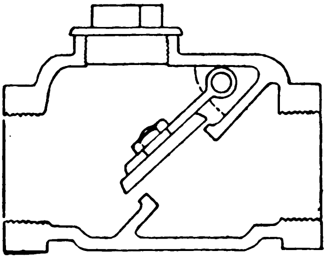


Fig. 39.

In doing with a less number of return risers, and returning the radiators into a dry return, as Fig. 29, there is no such certainty of noiseless working as when separate returns exist, but with care the noisy demonstrations can be greatly limited to the hour of first heating up. Some engineers call this apparatus the ordinary two-pipe system of steam heating work, which would make it appear as if the apparatus with separate return risers were a novelty or experiment. It is not so, and the two methods of doing two-pipe work can be correctly divided, the piping with separate return risers being considered essential for good work in hotels, or wherever noiseless working is required, and that with the radiator returns branching into a general return riser being possible for several business premises. The actual distinction amounts to whether a little noise is admissible or not.

With the latter system it is still best to have a wet main return (submerged or artificial), as this restricts the noises, or any irregular features that may occur to the risers and branches. There is then no complication with the mains, and little chance of the boiler water level being disturbed.

The area of a 1-inch pipe can be allowed for about every 140 square feet of radiating surface for the steam main; while the return should be one size smaller pipe up to 3 inches.

SIZES OF SUPPLY AND RETURN MAINS AND RISERS,
TWO-PIPE LOW-PRESSURE STEAM HEATING.

Square Feet of Radiating Surface (including mains if not protected).	Steam Supply.	Return.	Square Feet of Radiating Surface (including mains if not protected).	Steam Supply.	Return.
100 to 140	1 inch	¾ inch	800 to 1200	3 inch	2½ inch
125 to 200	1¼ „	1 „	1200 to 1800	3½ „	2½ „
200 to 300	1½ „	1¼ „	1800 to 2500	4 „	3 „
300 to 500	2 „	1½ „	2500 to 4000	6 „	4 „
500 to 800	2½ „	2 „			

When the conditions are favourable, the work being near the boiler, yet well above it, the pipes will deal with a little more radiation than is given above.

Professor R. C. Carpenter considers smaller returns adequate to carry the condense water even with small sizes of mains, as follows:—

Diameter, Steam Pipe.	Diameter, Return.	Diameter, Steam Pipe.	Diameter, Return.
1½ inch	1 inch	3½ inch	1½ inch
2 "	1¼ "	4 "	2 "
2½ "	1¼ "	5 "	2½ "
3 "	1½ "	6 "	3 "

Of course, if return pipes were made proportionate to the difference in volume between steam and the water it condenses to, then they would be very small indeed; but this is not possible in practice.

The minimum size of horizontal steam main (unless it is to serve one radiator only) should be 1½ inch. Mains exceeding 100 feet in length should be increased to one size larger pipe than those given in the foregoing table, for every additional 50 feet.

DIAMETERS OF RELIEF PIPES (Carpenter).

Steam Main.	Lengths of Steam Mains.			
	Up to 100 Feet.	200 feet.	400 feet.	600 feet.
Up to 2 inch .	½ inch	½ inch	½ inch	¾ inch
" 3 " .	½ "	¾ "	¾ "	1 "
" 4 " .	¾ "	¾ "	1 "	1½ "
" 5 " .	¾ "	1 "	1¼ "	1½ "
" 6 " .	1 "	1¼ "	1½ "	1½ "

Tappings and connections for radiators, two-pipe work:—

Radiators.	Supply.	Return.
Up to 48 square feet . .	1 inch	¾ inch
38 to 96 " . .	1¼ "	1 "
Above 96 " . .	1½ "	1¼. "

Indirect radiators should have one size larger connections for both flows and returns, as the condensation is more rapid.

THE OVERHEAD OR DROP SYSTEM.

In this system of apparatus the steam supply main is a vertical one, going up the building to the highest floor to be heated, and having no radiators on it until it commences to descend and make its way back to the boiler as a return. It is a one-pipe system, much as that already described, but the mains are vertical instead of being horizontal. The radiators are connected by a single-pipe connection. Fig. 40 illustrates the principle of this system, and it will be seen to possess a fault in having its flow main of considerable length and run in a manner that will only admit of the steam and the condense

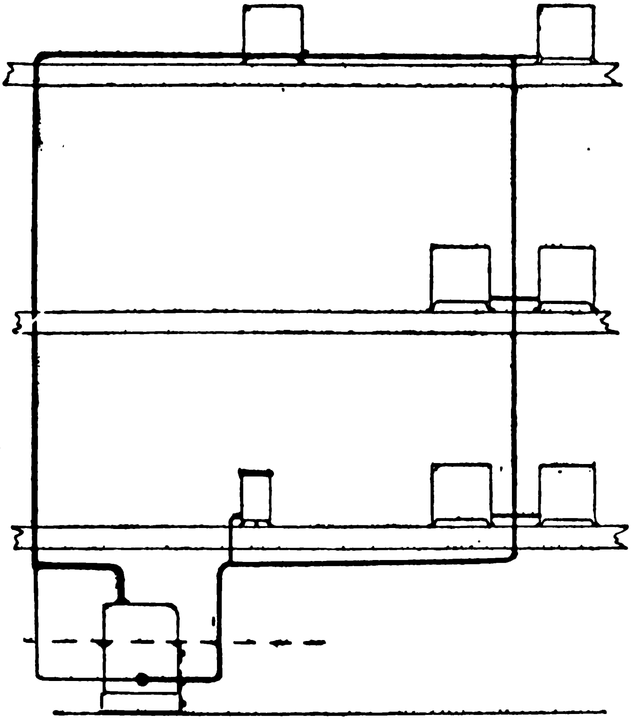


FIG. 40.

water travelling in opposite directions in it. It does not, however, carry any water from radiators or tributary pipes, consequently the fault can be reduced, if not quite overcome, by well covering the pipe to prevent loss of heat. Assistance can also be afforded by having the pipe as vertical as possible, and putting a relief or drip pipe at the foot where it turns to the boiler, as shown.

In the illustration a single circuit is shown, but should the work be extensive or the radiators scattered, there can be as many returns as desired to meet the case, though all must come down separately to a wet return, if the apparatus is to be noiseless. There may not be any occasion to have more than one steam supply main to a number of returns, although two or more can be used if desired, or one main may be branched. The radiator connections are single pipes, rising from the main to the radiator, and in these there must necessarily be steam and water travelling opposite ways. On this account the branches should be as short as possible, otherwise they must be of large pipe to prevent a conflict between the steam and water in them.

There is no doubt that this system is quite an ideal one, in obtaining a perfectly free and rapid flow of condense water towards the boiler, and as the pipes are vertical the water cannot fail to travel fast, so fast that the steam would not be likely to find it ever bar its progress or be troublesome in any way. It is considered that this overhead system is specially adapted for warming buildings let as offices, or used for any purpose, in which the basement is a valuable space and commands good rents. With other systems the mains are at the basement ceiling, having an unsightly appearance and doing no good. With this system the return main or mains can come under the floor in a channel, which leaves the walls and ceiling clear.

Or take an instance of some riverside premises which have no basements, and the lowest level is the ground floor, the most valuable of all floors. A network of ceiling pipes would greatly detract from the value of the offices and do nothing towards heating them. With the overhead system, with the returns beneath the floor, the pipes are not in sight, and they aid a little in warming the place.

It may be noted that, in the instances just referred to, *if the boiler cannot be sunk below the lowest floor where radiators are required*, then it becomes necessary to drain the condense water into a tank sunk in the floor, and from here the water must be pumped up to the boiler. If this is not done then the water level in the boiler and in the return pipe will be above the tops of the radiators on that floor, and the radiators will be almost cold. In other words, the conditions just stated do not admit of a wet return of the ordinary kind. The returns must run into a condense water tank below the floor level. If the boiler is below the floor, then all the returns come to this, unless an artificial water-line can be arranged beneath the floor. See Fig. 36.

The general conditions and details to be studied with this system of apparatus are very similar to the one-pipe system, page 39, to which the reader is referred. The sizes of mains, risers, and radiator branches are the same as with one-pipe work, and which are given on page 63.

If desired, the radiators can have two-pipe connections, so as to obviate the chance of conflict between the steam and condense water which have to travel in opposite directions in a one-pipe branch. In this case a return is taken from the further end of the radiator ; and this, to ensure noiseless working, must go down below water-line before entering the main return or the boiler. The supply branch to radiator would then fall, not rise, so as to drain into the radiator.

CHAPTER V.

DESIGNS OF STEAM HEATING APPARATUS WHICH DO NOT RETURN THE CONDENSE WATER DIRECT INTO THE BOILER, INCLUDING EXHAUST STEAM WORKS.

WHEN a building is heated by steam in the ordinary way it is not usual for heat to be required in the basement, consequently there is seldom any difficulty in getting the water to flow back to the boiler, either above or below water-line, as circumstances demand. When, however, heat is required, or a steam supply needed for any purpose, at a point level with or below water-line, it becomes practically impossible for the condense water to flow back into the boiler without assistance or force of some kind. The water-line being level with the heating device, whatever it is, would cause the latter to be filled with water if it was in direct communication with the boiler by its return pipe; and this is avoided by draining its return into a tank or trap at a lower point, and not communicating directly with the

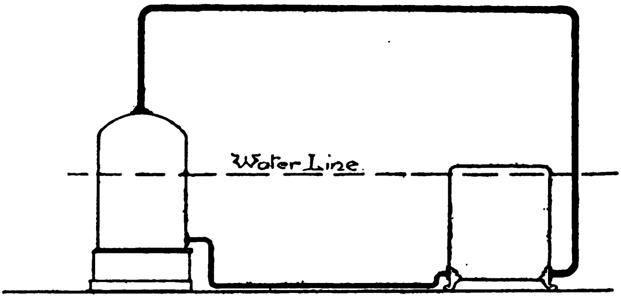


FIG. 41.

water in the boiler. Fig. 41 will show in a simple way that the water-level will be alike in both boiler and radiators if they both stand on a level, and a return pipe connects them.

No arrangement of check valves would remedy this, and recourse must be had to draining the condense into a tank or trap as Fig. 42. (This shows one-pipe connections, but two-pipe can be used if desired.) If it is a tank it must of course be closed, and there should be means of knowing when it is full. The water, which would be hot, could be used as feed water for the boiler, and every degree of its heat above the temperature of the cistern water represents a fixed amount of fuel saved if it is returned. It is of course distinctly economical to supply a boiler with water that only requires a minimum of fuel to make it into steam. This is supposing the boiler has to be frequently fed, as is the case when the whole of the condense water does not automatically return to it.

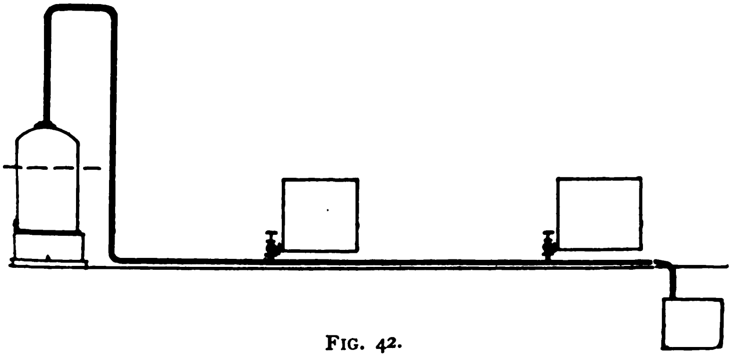


FIG. 42.

If a trap is used instead of a tank, the water can still be saved, but quite commonly it is discharged to waste, or perhaps put to other use. These traps will be found described in the chapter on appliances. They work automatically, and are made in sizes suited for various volumes of condense water. Their function is to discharge condense water without allowing steam to escape. Lifting traps are a steam tight variety that will discharge condense water above their own level at a height according to the pressure of steam in the service they drain.

It is thus possible to elevate the condense water to a point above the boiler level, but it will be into an open tank, not into the boiler.

It is possible and feasible to have a steam heating apparatus returning as much as possible of its condense water direct to the boiler, in the manner described in the last chapter, and at the same time having a low section draining into a tank or trap. Fig. 43 will give some idea of this. By getting as much as possible of the water to return direct there is the least loss of heat, and the least falling in water-level in the gauge. There is no gain, quite the reverse, in causing all the condense water to drain away from the boiler when the major part can be made to flow back by gravity without assistance.

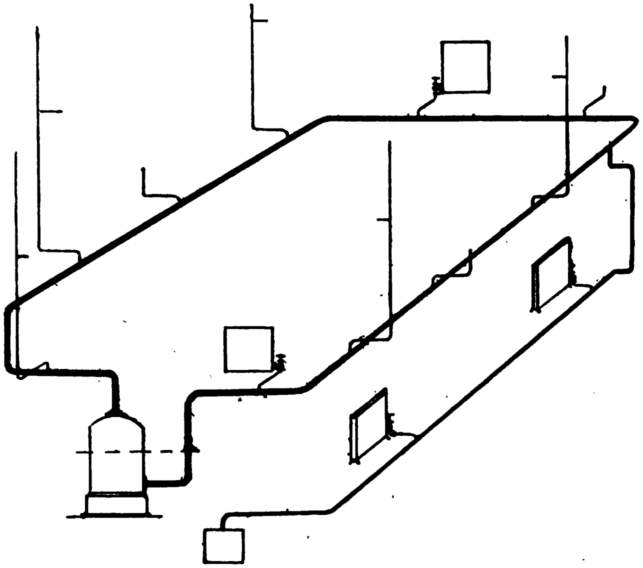


FIG. 43.

The water gauge on the boiler always requires watching, and the water in the boiler needs frequent replenishing when the condense water does not return directly to it. This makes a steam plant, working under these conditions, unsuited for a place where it would only be in charge of an unskilled person, such as at a church, a residence of moderate size, a private school, or any building not employing an engineer or mechanic. In other places, such as large institutions, board-schools, large business premises, and the like, there is no objection to the system, although it still remains the best to return the condense water direct to the boiler, if it be possible.

Heating by Steam from Engine Boilers.—A heating engineer, particularly in manufacturing districts, is often asked to heat offices or workrooms by steam taken from the power boilers that exist, and which are then furnishing steam to the engines. This is generally spoken of as heating with "live" steam, this term being used to distinguish it from "exhaust" steam, which is the same steam after it has passed through the engine cylinders. Live steam is taken direct from the boiler, and it may be said here that no engineer should recommend doing this under ordinary circumstances, if exhaust steam is available. Live steam may be said to represent new unused fuel when compared to exhaust steam, which is a waste product and costs nothing. There is, therefore, an immense difference in the cost of the resulting heat from the two sources. Heating by exhaust steam is fully spoken of later in this chapter.

In heating by live steam a service is taken from the boiler or from any active steam service, and the customary practice is to immediately reduce the pressure. A pressure reducing valve, a kind of governor, is put in the heating service immediately (within a few feet) it starts, and this causes the steam flowing from thence to the radiators to be at a lower pressure, say 5 lbs. to the square inch, or whatever the engineer considers as "low-pressure."

The pressure in the boiler or the steam mains from the boiler may be anything from 50 lb. per square inch upwards, and the reason for reducing this pressure is that the ordinary radiators, valves, and heating appliances cannot be expected to bear it. If the heating were not of a particular character as regards appearances, or the existence of dangerously hot pipes, then the full pressure could be carried, for radiators might be dispensed with and the whole apparatus, including the radiating surfaces, be made up of wrought steam tube. The surfaces would certainly be very hot, sufficient to make any settling dust or dirt give off an odour, but this might be considered as compensated for by the greatly reduced expense and the possibility of having the condense water flow back direct to the boiler, as with the gravity systems explained in the last chapter. The lessened expense would be in the absence of the reducing valve, the cheapness of erection, and the lessened area of radiating surface required by high pressure steam with its high sensible temperature.

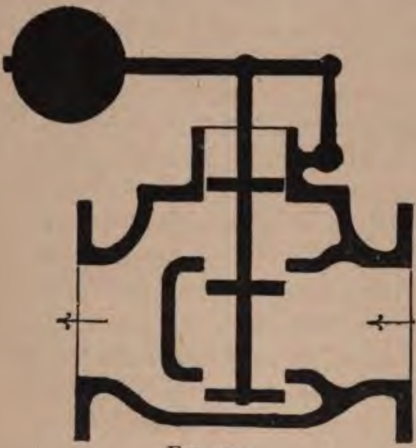


FIG. 44.

When the initial pressure of steam in a power boiler is only 30 lbs. per square inch (it is seldom as low) there is no objection to using it in an ordinary piping scheme with radiators, without reduction (without passing it through a reducing valve). Radiators, provided they have metallic joints, not rubber, will stand both this heat and its accompanying temperature. The writer has some working with live steam at 60 lb. pressure quite satisfactorily; but it is not considered a commendable practice to have radiators carrying steam at a pressure as high as this, although the radiators, previous to being sent from the makers, may be tested to much higher figures. It, however, would be a cold test.

Fig. 44 illustrates the principle of a pressure reducing valve, and there will be other illustrations found in the chapter on valves and fittings.

The piping scheme of a reduced pressure steam heating apparatus can be carried out on any of the principles shown in the last chapter. As explained with those examples the main steam supply service is carried to its highest point at the earliest possible moment, and from here it gradually falls, at least one inch in 20 feet, terminating in a feed water tank or a trap at the lowest point. A wet return can be easily made, if desired, as can be readily understood ; but, of course, it is of no use whatever attempting to return the condense water direct into the boiler. It can be easily guessed that trouble would ensue if a steam return pipe carrying 5 lb. steam were connected direct into a boiler making 60 lb. steam, particularly with connection below water-line, as it would be.

The details of this system are therefore (1) a short high pressure steam service, which must rise from its source so as to allow any water condensed in it to flow back to the boiler. Or if it is given a fall, it must be drained close to the reducing valve. (2) The provision of a suitable sized reducing valve, which is set to the pressure to which the steam is to be reduced. (3) From the reducing valve a system of steam heating apparatus, such as any of those described in the last chapter, but discharging its condense water into a tank or trap. (4) A draining or relief pipe on the steam supply service immediately it leaves the reducing valve, unless the pipe can fall from this point. If the low pressure pipe has to rise at all from the reducing valve, there may be a trickle of condense water coming back to the valve, and this must be drained away on the low pressure side of the valve, as will be understood. In other words, if there be a fall towards the valve either way there must be drip or relief pipes to drain away whatever condense water runs down there. It must not be expected that the water should pass through the valve either way. It is hardly necessary to say that these relief pipes must not enter the wrong returns. The relief from the high pressure side of the valve must not run down and terminate in the reduced pressure return or trap, nor *vice versâ.*

Sizes of pipes and other proportions will be found in Chapter IV., also details as to methods of connecting, provision for expansion, etc.

Heating by Exhaust Steam.—Where exhaust steam is available and heat is needed, and the time of making the exhaust steam corresponds with the time that the warmth is required, nothing can justify the waste of the steam. This applies in almost all places where steam is generated for power; in hotels and other buildings which make their own electric light, run their own lift and other machinery; in all manufactories and establishments employing steam power, and similar places.

Although steam may be practically valueless for power after it has passed through the engine cylinders, it has lost only a comparatively small proportion of its heat, and for purposes of warming buildings is at a high effective temperature. In this latter respect it is almost equivalent to a self-heating boiler, for the warmth is had without extra expenditure of fuel.*

The utilisation of exhaust steam for warming a building does not necessarily interfere with its being used for heating feed water. W. J. Baldwin gives it that not more than $\frac{2}{11}$ of the exhaust steam can be used in heating feed water; in other words, the warming of feed water from 40° to 212° F. can condense but $\frac{2}{11}$ of the steam that passes through the engine, thus leaving $\frac{9}{11}$ of all the exhaust steam to be utilised for other warming purposes. This is proved by the fact that to warm a pound of water from 40° to 212° takes 172 heat units, whilst a pound of steam has 966 units of latent heat. Feed water can be raised to a higher temperature if heated under pressure, by steam under pressure, but this means back pressure on the engine with bad results. As a rule it is good and considered satisfactory if the feed water is heated to 205° or 210°; and this, as stated, leaves a liberal margin of heat for other heating work.

In utilising exhaust steam for heating there are certain rules to be observed which have an important bearing on results. One of the most important is to free the exhaust steam of oil or grease. It will prove most detrimental if these substances get into the heating pipes and on the interior surfaces of the radiators. These substances also have a seriously injurious effect on the boiler if the condense water having oil in it be used for feed. Of course if the exhaust steam be first used for heating feed water, the condense from the remaining steam need not be saved for this purpose. The elimination of oil and grease, however, is still necessary, as only clean steam must be sent into the heating system.

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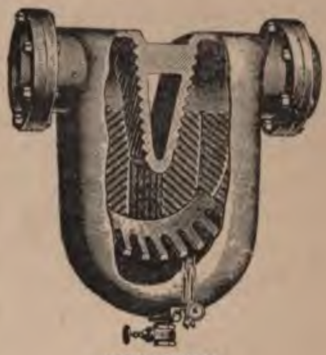
* This requires qualifying to a certain extent. Exhaust steam as ordinarily used for heating makes a back pressure on the engine of a few pounds, and this entails a certain extra expenditure of fuel. This is obviated in the next system explained.

Exhaust steam carries vapours of oil or grease from the lubricants used in the engine cylinders. As to the resulting effect of oil in steam boilers it is agreed by all to be destructive, but the manner in which this occurs is not fully admitted. It is probably a chemical action, but whatever it is the rule should be to use every means of preventing the admission of grease or oils into steam boilers.



HORIZONTAL.

FIG. 45.

The abstraction of oils from exhaust steam is not difficult if care is used, and as this steam may be wet the appliances can be made to remove superfluous moisture also. The apparatus used for this purpose is known as a "separator"; and Fig. 45, showing an interior, will furnish an idea of the principle involved. There are no working parts. It is merely arranged that the steam passes through a passage lined with irregular surfaces, which, it is found, have the oily and watery vapours deposited on them. The surfaces are also so disposed that the abstracted liquids are properly drained away to the bottom outlet. The oil drip or collecting tube is sometimes an extension of the bottom of the separator with a water gauge on it. The collection of oil is then visible, and the proper moment for its discharge known. Some engineers always leave the discharge tap open just a trifle, so that oil is ejected as fast as it arrives. Some put a trap to m the discharge occur automatically. Briefly, the separato needed to clean and dry the steam, and the products of this process have to be disposed of from the separator.

An excellent arrangement has been suggested in which a large closed tank is fitted internally with baffle plates to catch the oil and water, and this acts as the separator. Its size is suggested as thirty times that of the engine cylinder, the object of this being to equalise pressure and to minimise back pressure and shock.

The exhaust from an engine is delivered in strokes or jets, and is not an even continuous supply, and it is delivered to the heating mains, whether it is wanted or not; that is, the steam may be in excess of what is needed in the mains. Relief is given to this by what is known as a "back pressure" valve (a valve to relieve back pressure really, and which will be referred to directly), but it does not prevent the general supply of steam being delivered irregularly or with irregular strains. Again, the amount of steam from an engine may vary considerably in one single hour, for the governor on the engine is provided solely to regulate the supply to the amount of work being done, so that the amount available for heating may vary in one plant, within rather wide limits.

The large tank separator will greatly minimise variations, and do as much as possible towards making the supply of steam in the heating system uniform in volume, flow, and pressure.

The next detail to be considered is that of back pressure on the engine piston. It is very seldom that a heating apparatus can be so exactly designed as to take precisely all the exhaust steam made. If the steam is a little below sufficient it may expand into the system and fill it, but if in excess it must undergo a check to its free disappearance, and be compressed more or less. As the heating system will be sealed this confinement of steam under compression must exert whatever compressive force it has back on to the piston which is driving it out, and this is known as back pressure.

If the heating system were small it might be possible to work it with an open discharge pipe, so that the exhaust would simply blow through and escape; but with a system of circulation and branches this is not feasible, and the discharge termination of the system must be in a tank or trap. The exhaust steam is therefore confined; and, as stated, if it be supplied in excess of what is immediately condensed in the radiation, it must be under pressure in the pipes and press back equally on the piston. The fault of this, needless to add, is that more live steam from the boiler is needed to overcome the extra work the piston has, and as live steam means new fuel an extra expense is incurred.

This expense in fuel may be considered as the cost of the heating, and it can be practically obviated by adopting one of the systems explained later, but under ordinary conditions the cost of fuel involved by the back pressure is not very great, that is, the heat is obtained very cheaply indeed at this price. The actual loss is the difference between the pressure in the cylinder and the back-pressure; thus, if the steam in the cylinder is 50 lbs. per square inch and the back-pressure 4 lbs. per square inch, then the loss is 8 per cent. to the engine. This represents a low price for the heat.

It is here stated that the back pressure may be 4 lbs. per square inch. This is when a back pressure (preventing) valve is used. If this valve were not used then it would be possible, by putting a small heating apparatus on a large engine, to have a back pressure nearly sufficient to stop the engine working. The back pressure valve is designed and provided expressly to limit the back pressure, and the more it is limited the less the loss to the engine must be. In summer or at any time these valves can be thrown wide open, so as to obviate back pressure entirely when the heating apparatus is not in use.

Fig. 46, which gives the section of a valve, will illustrate the purpose it serves. It is placed in the ordinary exhaust pipe from an engine, its purpose being, when looked at in this way, to divert the exhaust steam into the heating system, but it is a balanced valve which can be set to open at any pressure ranging from 0 to 10 lbs. per square inch. If the heating system is an extensive one it may not suffice to set the valve at 2 lbs. to the square inch, it may have to be 5 lbs. If the heating apparatus is quite small a pressure of ½ lb. or even less may suffice. It would not be so economical as has been stated if there had to be a back pressure of 4 or 5 lbs. on a large engine to supply heat to two or three radiators. With so small a number as this within a reasonable distance, the pressure need be but very trifling, or perhaps the steam might be blown clear through, the piping being open at the end.

The back pressure valve is therefore a means of diverting the exhaust steam from its ordinary channel into the heating system, but at the same time it is balanced so as to automatically limit the pressure in the system and the back pressure on the piston to the smallest sum that the heating work can be done with. With the ordinary method of using exhaust steam for heating a few pounds pressure must be kept to force the steam into the different (particularly the distant) parts of the apparatus, for although it may be said that as the steam condenses in a radiator, it requires little or no force to cause new steam to flow up into the vacuum, it is not this moment that the pressure is provided for. It is to clear the apparatus

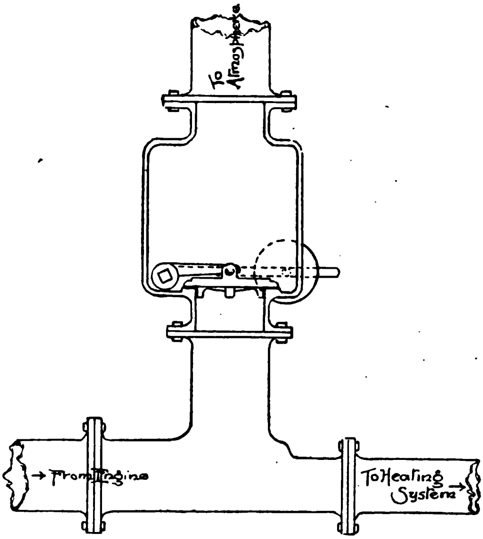


FIG. 46.

of air when it is heating up, and to fill it with steam at all parts. When an apparatus is properly piped, and this means using full sized pipes, 2 lbs. back pressure is ample for works of fair magnitude. With small works, well piped, it is possible to get good results with a back pressure barely visible on an ordinary gauge. It is, however, difficult to clear the apparatus of air, when heating up, with such a low pressure, although it would work excellently when once heated up, and in full use. It would seem as if a back pressure valve was needed that would automatically provide for a pound or two extra pressure for a short time when heating up, and to work at a minimum pressure afterwards. The engineer can arrange this, however.

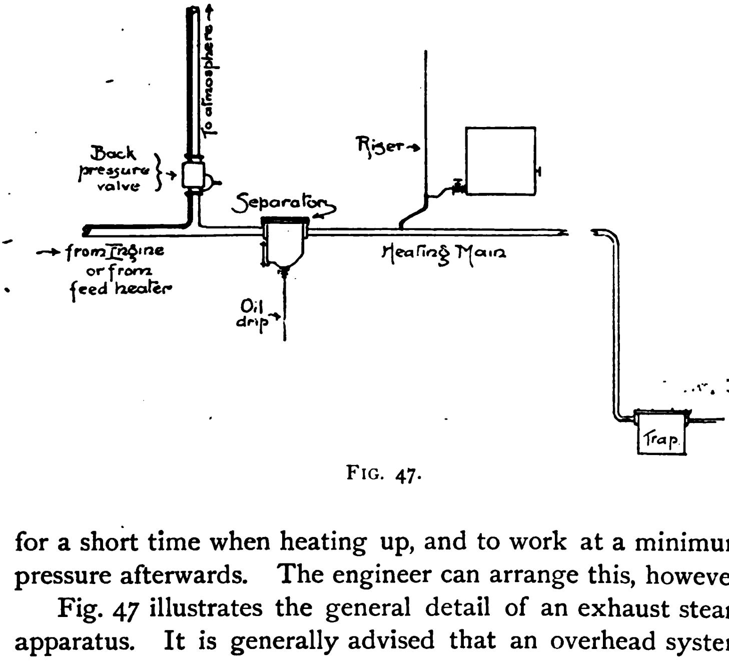


FIG. 47.

Fig. 47 illustrates the general detail of an exhaust steam apparatus. It is generally advised that an overhead system be adopted where possible, thus providing for the separator being placed at the highest level, and the heating branches or mains descending from this to the various points required. Fig. 48 shows this with the tank separator recommended.

In regard to the sizes of pipes, main and branch, required in the heating system, the tables given on pages 63 and 79 can be referred to. On no account should these sizes be reduced. They may be increased with advantage, and whenever the radiation figures work out for a between size then use the size above, not below. The exhaust steam being delivered into the heating system at what is called low pressure makes the system work under conditions analogous to those described in Chapter IV., so far as the area of pipes is concerned.

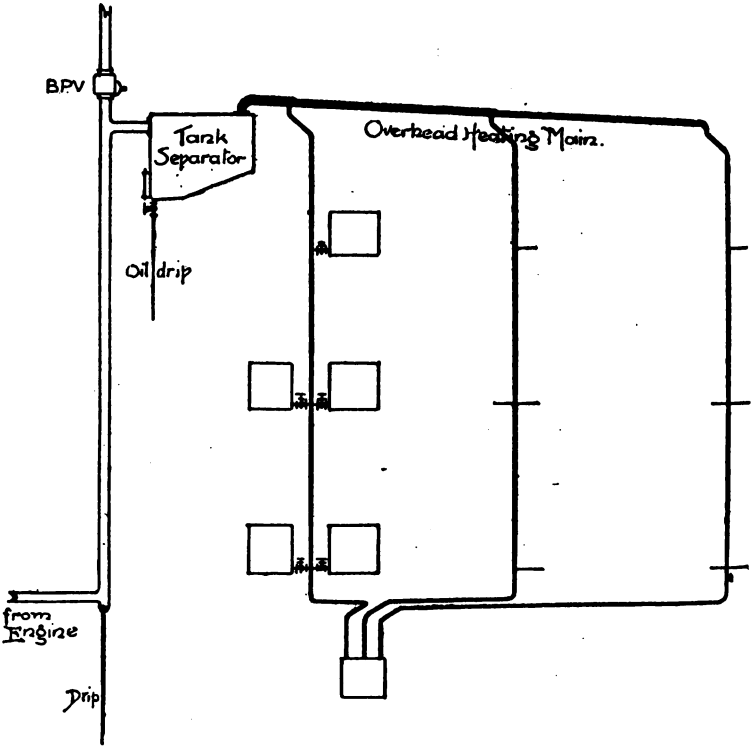


FIG. 48.

The following table is useful in determining what amount of heating work can be done by the exhaust steam at disposal, and showing the size of exhaust pipe, which however probably exists, or will be put in by a different engineer. Whenever doubt exists it is practically impossible to err by using larger pipes.

SIZE OF EXHAUST PIPE, HORSE-POWER OF ENGINE, AND RADIATING SURFACE THAT CAN BE SUPPLIED.

Diameter of Exhaust Steam Pipe, not exceeding 100 feet long.	Nominal Horse-power of Engine.	Radiating Surface supplied, in square feet.	Diameter of Exhaust Steam Pipe, not exceeding 100 feet long.	Nominal Horse-power of Engine.	Radiating Surface supplied, in square feet.
Inches			Inches		
1	1⅛	170	3½	23	3450
1½	3	450	4	36½	5475
2	6½	975	5	63	9500
2½	11	1650	6	99	14850
3	17½	2600			

Notes on Table.

It is assumed that the engine is at full work.

If feed-water is to be heated the amount needed for this, say one-fourth the whole, must be deducted.

The above figures are based on 150 feet of radiating surface being heated by one horse power.

The exhaust-pipe is smaller than a low-pressure steam main would be, as it has steam at a higher pressure and greater volume travelling up it. This is taken by the heating system, causing no back pressure on the engine, and not lifting the back pressure valve, until the heating system is filled and kept full. It would, however, be distinctly better, as being without risk, if the exhaust pipe was larger, assuming the heating engineer may have a word in settling its size. With a larger exhaust pipe (one size larger all through) there would be better opportunity of heating at the lowest practicable pressure and back-pressure.

Of course no exhaust steam can be had for heating from a condensing engine, but it is commonly considered advantageous in such a case to have the condensing plant cut off during the winter, so as to use the exhaust for heating, condensing in the warmer weather only.

On the other hand, there are instances in which the whole of the exhaust is insufficient for the heating required, and it is only used as an auxiliary to live steam, or it had better be said that the live steam is an auxiliary to the exhaust. Skill is required in arranging this, for the steam comes from two sources at different pressures ; at least the pressure must differ to some extent, however carefully the valves are arranged. It is best to let the reduced pressure of the live steam be lowest, as this will not involve complex results, as might be the case if the live steam were at a higher pressure than the exhaust. Fig. 49 gives an idea of the arrangement, and the reducing valve, where marked, keeps the live steam pressure reduced.

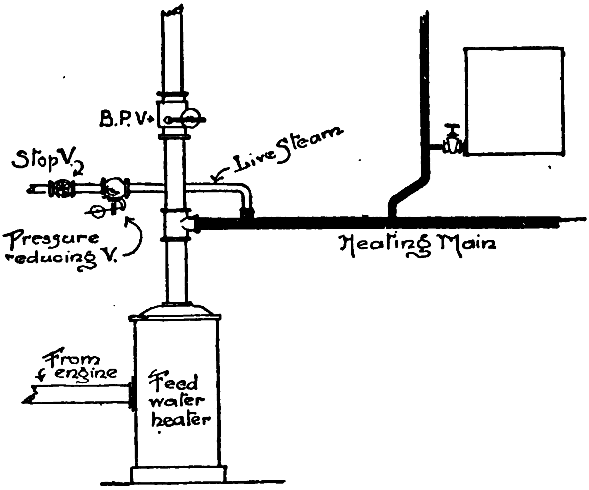


FIG. 49.

There would be no objection to feeding a heating system with live and exhaust steam independently, using wholly exhaust when it was to be had, and using wholly live steam when the exhaust failed (engines stopped). Such an occasion may not be common, but to effect it there would only need to be a live steam service (with reducing valve) laid on to the system (on the radiator side of the separator), with stop valve to shut off the exhaust as required. The back pressure valve need not be touched if steam was only used when the engines were not at work. If they were at work at this time the back pressure valve should be thrown wide open.

The best advice that can be given to an engineer having rather limited experience of this work is not to attempt to heat by a combination of live and exhaust steam as auxiliaries to each other. If the exhaust be insufficient for the whole system let it do part, and do it quite separately. Use live steam for the other part, also quite separately. No connection should exist between them, each apparatus being distinct and complete in itself. It makes comparatively no difference in the cost or in the attention needed.

A final word concerning this section (and the succeeding one) relates to the separator. No negligence must be allowed here. If by inattention or other cause it is not allowed to discharge its oil often enough it will get loaded with oil itself, and lose its cleansing qualities on the steam. The steam will then carry oil into the heating system, and quite spoil its efficacy. It can be readily understood that no practicable means exist to remove the oil from the internal surfaces of radiators, to clean them, therefore, the ill effect is both bad and lasting. If there be the least doubt about the separator having regular attention, it will be found best to open the oil drip cock just a little, and leave it so that the oil comes out as fast as it arrives. This means a little waste of steam, but the cock can be set carefully, so that the issue is little more than oil and water only.

Heating by Exhaust Steam at or below Atmospheric Pressure, or the Vacuum System of Steam Heating.—This system of apparatus has, undoubtedly, a great future. It is a system that is not applicable to small works, and scarcely to places where there is no steam power. It excels with exhaust steam, and as a manufacturer, who has a large factory heated by exhaust steam, correctly said, the coal bill is no heavier in winter than in summer, meaning that the large heating plant was supplied with steam for absolutely nothing. There is no back pressure. Briefly, the special efficacy of the apparatus depends on two things: (1) the more perfect extraction of air (it is extracted, not driven out); (2) the creation of a partial vacuum in the heating system, which causes steam to freely and rapidly flow to all parts, near and remote, even at or below atmospheric pressure. It is said that an open exhaust pipe can be used, yet the exhaust steam will freely pass into the heating main on account of the vacuum there making it the direction of least resistance.

The systems base their efficacy on the apparatus being emptied of air first, and the steam being drawn in afterwards. The ordinary systems (exhaust or new steam) force the steam in, this in turn having to force the air out and make its way wherever required. It has been said to amount to all the difference between pulling and pushing a rope. The former is positive in its effect, the latter uncertain, even with a short rope.

Taking the question of air first, this has a most important bearing on the subject of steam heating, whatever system is adopted. It is not a question that can be lightly passed over; for its effect, good or bad, can make all the difference between success and failure. In a hot water heating system, the question of air has also to be studied, but its action is so easily understood and well known that difficulties can readily be overcome. In any case it is by no means impossible to get rid of the air by some means or other on account of the great difference in specific gravity (weight) of water and air. Just the reverse of this applies with steam and air which are—compared with water and air—practically of the same weight.

It may be said with a steam heating apparatus (not an extracting system) that the air is never properly got out, nor anything near properly. It collects in all sorts of places, and is proved to be hanging or clinging to the inner walls of radiators. It does not stop the flow of steam perhaps, but gives trouble by preventing the radiators getting hot. Sometimes only half a radiator will heat, sometimes they will heat in patches, and always give more or less trouble, which does not grow less with use or by care with the water. As a steam apparatus is filled with air (by the opening of the automatic air vents) each time it is cold, the air is a constant trouble and it is variable also. Even if an apparatus should be constructed without automatic vents, and sealed everywhere, still air will get in. As water can and does absorb about one-twentieth of its volume of air when cold, there is air supplied to the apparatus with any water added. Apart from this, it is considered impossible to make a steam apparatus that will remain hermetically tight for all time.

The whole trouble with air, and it is a very real trouble, is owing to the steam being required to force the air along and expel it. This it can only do partially, because of its mixing with it, and there being no great difference in their weights to separate them. With air in the radiators the heat radiation and general efficacy is reduced. With all the air extracted from the radiators, the efficacy is at its highest, and in this latter rests one of the advantages of any vacuum system. It is a very great advantage.

Whilst on the subject of air it may be mentioned that as a vacuum system extracts the air and discharges it quite away (into the atmosphere), there is the further agreeable result that its odour is not perceived in the room. Exhaust steam gives an odour, and it is intensified when the apparatus has had exhaust steam through it for some time.

Taking the question of steam circulation by exhaustion next, as compared with the ordinary plan of forcing the steam into the piping system, the general increase in efficacy is most pronounced. There may not be any economy in the amount of steam used if both worked under the same conditions as regards the prior removal of air from the pipes and radiators, but there is a saving in fuel by the absence of back pressure. One authority states that the total fuel saving amounts to 12½ to 15 per cent.—a large item—when the system is applied to an existing ordinary apparatus having the piping well arranged. If an apparatus having the pipes of small size and badly arranged be converted, the saving in the coal bill may be double this, or even more.

By creating a partial vacuum in a steam-heating apparatus there is the greatest possible certainty of the steam entering that space. It means a positive flow or circulation of steam.

Radiators doubtfully connected, pipes a little too small, distant radiators, a slow flow of condense water in the mains, and other faults, all show improvement in their respective ways, a total removal of the fault being experienced in many cases. The steam will travel further under less favourable conditions, and will not be so ready to have conflict with condense water, and as to trouble with air this is quite overcome, as already explained. The additional great advantage is obviating back pressure on the engine piston, and, if anything, assisting power.

The system can be adopted with live steam, but the question of back pressure relief does not then exist. There is, however, still the advantage and gain of air removal,* very low pressure of steam (with the more agreeable temperature of a hot water apparatus) and certainty of flow or circulation.

To show how certain the circulation is, a somewhat remarkable test may be quoted. A very large building was heated by warm air on the plenum system, the air being driven through a huge heater containing 24,150 feet of 1¼-inch pipe. This pipe was heated by exhaust steam with 4 lbs. back pressure on the engine.

The exhaust pipe (from a 400 horse-power engine) was 10 inches diameter, and was carried up 30 feet to the atmosphere, after running a few feet horizontally to get through the wall. It was of course fitted with a back pressure valve. The pipe carrying the exhaust steam to the heater was of 6 inches diameter, and 170 feet long. When the system was attached the interior parts of the back pressure valve were removed, so as to leave the exhaust quite open and clear; yet notwithstanding this, the exhaust steam passed through the long 6-inch pipe, and filled the miles of 1¼-inch tube in the heater in preference to going through the clear 10-inch pipe some 30 feet to the atmosphere. It is, however, not difficult to understand this, when it is seen that the atmosphere offered greater pressure resistance to the steam than was offered by the partial vacuum of the 6-inch pipe. Steam, like other fluids, will travel the way of least resistance.

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* When air is in a steam radiator the prime surface is greatly reduced, prime surface being that which has steam in actual close contact, and which is of the greatest effectiveness.

The result of the test was simply this :—

	Before application of the system.	After application.
Back pressure on engine . .	4 lbs.	0
Temperature of heated air . .	130° F.	148° F.

The temperature of the air before heating was in both cases precisely the same, and the volume of air passed through the heater in a given time the same.

There are two recognised systems by which these results are obtained, but they operate differently. They are of American origin—one the Paul system, the other the Webster system.

In the former a reliable automatic air vent is fixed on the radiator or coil in its usual position, and from this a small air pipe, generally ¼ inch, is taken down to what is called an "exhauster." This air pipe can have connection with any number of radiators that it passes on its way, but as the numbers increase its size should be made a little larger, say ⅜ or ½ inch. Any number of these air lines can come down to the exhauster, or they can run into a ¾ or 1 inch air main, which runs to the exhauster. There is no water in the small pipes or the main, only air. The exhauster acts much like an ejector working with live steam, or with water, under a pressure something over 20 lbs. to the square inch. It can be understood that an ejector working under these conditions will quickly extract or exhaust the radiators and pipes of air (the automatic air valves being open while the apparatus is cold) ; then immediately the air is gone and the steam follows up, its heat closes the valves, and the exhauster stops work. The exhauster is always put to work a little time before the steam is turned on, so as to create the required partial vacuum, and to make sure that the remaining air will all come away in front of the steam. Fig. 50 illustrates the principle, and the American company who run this system give the following brief explanation of its construction and operation :

"An automatic air valve is placed on each radiator, coil, or indirect stack, and connected with an air riser. The air risers are run down beside the steam risers, and brought together at some convenient point in the boiler or engine room, and there connected to the exhausting apparatus of the system. Before the steam is turned on the plant the exhausting apparatus is put in operation, and the air contained in all the heat distributors is quickly removed, each radiator, coil, or stack in the building being maintained in the best possible condition to receive steam.

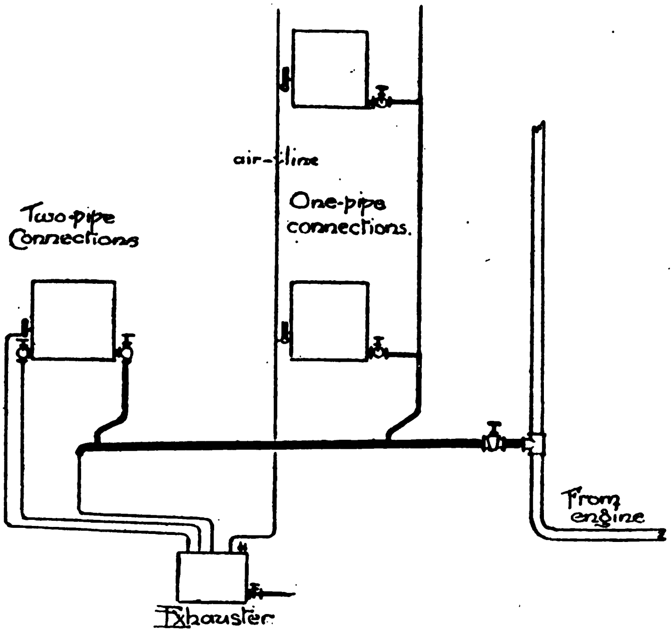

FIG. 50.

"Upon opening the supply valve the steam flows naturally and *without pressure* into the radiators, coils, etc., and its heat closes the automatic air valve. In the process of condensation a great deal of heat is given off by radiators in the form of "radiation," and the volume of steam is being constantly decreased in the ratio of 1700 to 1. Such decrease creates a constant flow towards the heat distributor, which is provided for by an additional steam supply. Means are also provided for the subsequent removal of air as rapidly as it collects, and therefore all the heat distributors in the heating plant are maintained at all times in a uniformly efficient condition to perform their office."

The Webster system works differently, as it not only deals with the air, but with the condense water also. It extracts both. The extraction or exhaustion is effected by a small vacuum pump, operated by live steam, and to make it automatic this can in turn be controlled by a pump governor.

In this system what is called a thermostatic valve is used (an automatic air valve could rightly have this title if desired), and this is fixed at the opposite end of the radiator to that at which the steam supply enters. In other words it is fixed to the radiator where the return connection is made with an ordinary two-pipe system. From these valves return lines or risers are taken much in the same manner as the air lines of the Paul system, but they have to be of a sufficient size to carry the condense water.

When the apparatus is cold the pump is started, which quickly extracts the air and makes the required partial vacuum.* The steam is then allowed to flow in, and the heat of this when it has filled the radiator closes the valve. In this case, however, the valve re-opens when the condense water has collected sufficiently, and the removal of this is at once effected.

It is a plan that affords little opportunity for the condense water to prove troublesome, and it is also a very helpful method to apply to an existing apparatus which is troublesome in this respect. A great number of steam-heating apparatus exist in which the piping is smaller than it should be, and the Webster system is eminently adapted for remedying this failing, either wholly or partially.

A particularly striking detail of this system, and which is probably unobtainable in any other, is that the flow of steam into the radiator can be regulated and the temperature modulated to any extent, like a hot water radiator. This has been the troublesome feature—a fault, in fact, with steam as a heating agent; for, with the ordinary apparatus, whether it be a one-pipe or two-pipe method, the valves have to be full open or close shut. In the system under discussion they can be opened to any degree, regulating the supply of steam and the resulting warmth accordingly, and no noise accompanies this. It is difficult to overrate this advantage, for it is badly wanted in the ordinary gravity steam plants. The regulation is wholly by the supply valve to the radiator, the special discharge valve being automatic.

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* The term "partial vacuum" is used, because a perfect vacuum is not obtained.

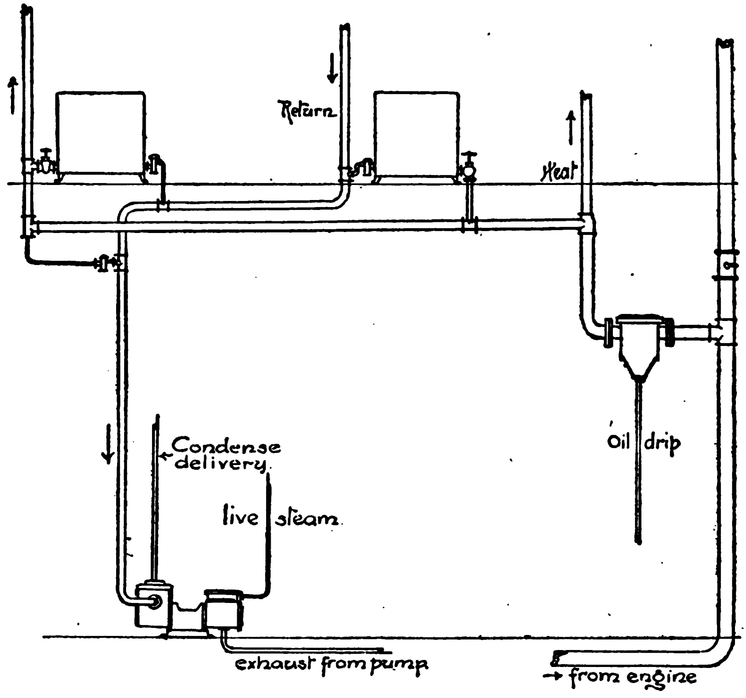

FIG. 51.

Fig. 51 illustrates the general details of this system. The thermostatic valve has a section as Fig. 52, the working part consisting of a composition stem or pencil, which expands or contracts as the temperature rises or falls. By its expansion communication between radiator and exhaust return is closed; by contraction it is opened. It is adjusted, after being fixed, by the top seating, which screws up and down and can be set so that the passage will open at a trifling degree less temperature than the steam. The condense water, when it collects, causes the composition stem to contract, by being of a lower temperature than the steam, but while the condense water is small in quantity and steam touches the stem it remains expanded and closed. It acts the same as an automatic air valve (as explained in a later chapter on fittings and appliances). The connections are as Fig. 53 when attached to radiators as described, but the valve can be put to other purposes, such as draining relays, risers, the ends of horizontal mains, etc. The valve in this illustration is of angle shape, but operates in the same manner as Fig. 52.

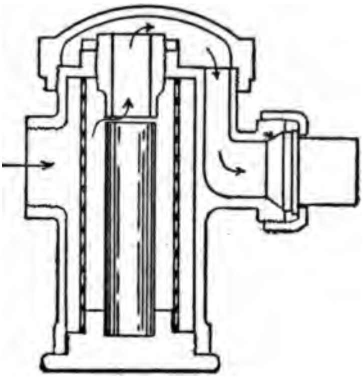

FIG. 52.

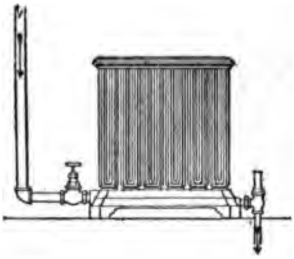

FIG. 53.

Another occasionally useful feature is that the vacuum pump will raise the condense water sufficiently that radiators can be had on the same floor as the engine or feed water heater without becoming waterlogged.

An authority has stated that with this system (more than with that which has only the air extracted) smaller pipes than usual may be used, particularly the returns. It is better, however, not to reduce the steam supplies, mains, or risers, below the sizes given in Chapter IV., but the returns may be reduced one-half in area. It is said that one-tenth of a square inch area in the return pipe is sufficient to each 100 feet radiator surface, this being little more than a $\frac{1}{8}$-inch pipe. This, however, is going to extremes, and a reduction of ordinary gravity returns (on page 79) by one half is sufficient.

A last word as to the advantages of exhaust systems is that a certain volume of steam can be made to go further and extend over a greater area as the result amounts to expanding the steam. A further detail is that lowness of pressure and the absence of back pressure admits of exhaust steam from compound or economic engines being used as successfully as any. Back pressure on the large piston of a compound engine is, needless to add, more serious than on a high pressure piston.

It will not be out of place to close this subject by giving the results of some disinterested tests made, no particular manufacturer or specialist having had any interest in them. The only disadvantage of vacuum systems will then be referred to and discussed.

The disadvantages of the vacuum systems are that the sensible heat of the radiating surfaces is reduced so that, it is assumed, a greater area of surface may be needed. The increased cost of construction as compared to an ordinary one-pipe system, also a little extra labour in attention and maintenance.

The one important point of these three is that relating to the area of radiating surface. Let it be supposed that a steam heating apparatus is being run with live or exhaust steam at 5 lb. pressure above atmosphere and a temperature of 227 degrees. It is proposed to adapt one of the vacuum systems to this, which will reduce the temperature of the steam to 212 degrees or less. It is quite recognised and allowed that a radiator supplied with steam at 212 degrees will not afford and maintain the same temperature to a room as if it were constantly filled with steam at 227 degrees, and it would therefore appear obvious that the radiation would have to be increased.

Notwithstanding this, the disadvantage, as plain as it is, does not exist. It is found in practice, also by experimental tests, that the abstraction of the air causes such a positive circulation and contact of the steam, making the radiator surface efficient to a degree that the ordinary method never gets it to, that the radiation need not be increased, not by a single foot. This, let it be repeated, is in the case of a vacuum system being applied to an existing system which has been previously working without a pump or exhauster, and having the air forced out by the inflowing steam as is usually done.

As explained later, when treating of the various materials used to cover heated surfaces to prevent loss of heat, air is most successful in preventing a transference of heat, provided the air is held and confined and is in small volume. Air is a good poor-conductor, and the efficacy of hair-felt, silicate cotton and the various compositions used to prevent heat loss is due, almost wholly, to these substances being a mass of minute air chambers. Dense solid materials are all better conductors, showing that air is the active agent in forming a barrier to heat transference.

The existence of air in a radiator is therefore an effective barrier to the heat being lost from it. If the air only lies as a film on the inner surfaces here and there, as it is believed to do, then its ill effect is as great or greater than if it were in larger bulk. With the exhausters of the vacuum systems, the more perfect removal of the air amounts to cleaning the inner surfaces, in a sense, and the result is a most marked increase in total efficacy.

TEST IN A LARGE BUSINESS BUILDING WITH OVERHEAD SYSTEM CARRYING SEVERAL THOUSANDS OF FEET OF RADIATION.

With Air Exhausting System.

Supply turned on at 5 A.M.
Exhauster started at 5 A.M.
Test 19 hours.
Pressure 1 lb. below atmosphere.
Used 4420 lbs. coal.

Without Air Exhausting System.

Turned steam on at 5 A.M.
Test 19 hours.
Pressure 1 lb. above atmosphere.
Used 5270 lbs. coal.

Temperature.		—	Temperature.	
Outside.	Inside.		Outside.	Inside.
degrees	degrees		degrees	degrees
33	57	At 5 A.M.	52	62
35	57	6 „	50	64
38	62	7 „	48	70
38	65	8 „	50	72
39	70	9 „	50	73
39	68	10 „	48	72
39	70	11 „	50	75
39	70	12 „	50	76
40	72	1 P.M.	50	76
40	72	2 „	50	77
42	74	3 „	48	78
42	75	4 „	43	78
42	75	5 „	45	78
44	76	6 „	44	78
44	76	7 „	43	78
Avg. 39·6	69·3		47·7	73·8

—	Number of hours run.	Outside Temperature in degrees Fahr.	Wind Velocity.	Barometer reading in inches.	Pressure in pounds in Heating System.	Vacuum in inches on Air Exhausting System.	Work done by the Electric Light Plant in E.H.P. per hour.	Work done by Elevator Plant in H.P. per hour.	Coal consumed in pounds.	Ashes removed from Furnace.
		First day. Air Exhausting System Disconnected.								
Maximum . . .	..	35·5	27·0	29·46	2·75	..	..	..	..	..
Minimum . . .	..	5·0	9·0	29·0	2.0	..	..	..	..	..
Totals and averages .	24	18·81	22·68	29·26	2·25	..	30·5	19·5	15,600	13·39
		Second day. Air Exhausting System Connected.								
Maximum . . .	..	18·0	12·0	29·55	0·25	12·0	..	..	..	..
Minimum . . .	..	7·0	4·0	29·37	0·25	8·25	..	..	..	..
Totals and averages .	24	12·14	8·49	29·50	..	11·0	33·32	19·75	12,900	17·32
		Third day. Air Exhausting System Connected.								
Maximum . . .	..	11·0	24·0	29·84	..	12·0	..	..	..	..
Minimum . . .	..	3·0	10·0	29·55	0·1	9·0	..	..	..	..
Totals and averages .	24	3·09	15·88	29·71	0·25	11·5	32·73	19·43	14,400	19·23

TEST IN A UNIVERSITY BUILDING.

—	With Air Exhausting System.	Without Air Exhausting System.
	Date of Test.	
	March 25, 1897, 7·30 P.M. to 7·30 A.M.	March 27, 1897, 6 P.M. to 6 A.M.
Duration of test	12 hours	12 hours
Barometer	29·41	29·41
Gauge pressure on main before passing pressure regulator	21·0	26·4 lbs.
Gauge pressure on main after passing pressure regulator	0·0	6·2 lbs.
Pressure on air line, vacuum	6·8	..
Average temperature, Fahrenheit, external	31 degrees	33 degrees
Museum thermometer No. 1	62·2	62·6
„ „ „ 2	64·8	64·8
Hall „	75·8	76·0
Room No. 18	74·2	74·17
„ 4	82·4	82·15
Library thermometer No. 1	68·1	68·8
„ „ „ 2	68·1	68·3
„ „ „ 3	69·5	69·7
„ „ „ 4	69·0	69·0
„ „ „ 5	76·36	77·3
Room „ „ 7	76·0	76·2
Total weight of return water	8·160 lbs.	9·578 lbs.
Temperature of return water	195·6 degrees	207 degrees
Steam used by exhauster per hour	36 lbs.	..
B.T.U. per hour for heating	607·340	783·490
Per cent. saving in B.T.U.	14·4	..
Per cent. saving by weight of steam	14·8	..

TABLE OF TEMPERATURES FOR PRESSURES BELOW AND ABOVE ATMOSPHERE.

Vacuum Gauge.	Absolute Pressure per square inch.	Temperature.	Volume of One Pound.
inches, mercury.	lbs.	° Fahr.	cub. ft.
27·9	1	102·1	330·36
25·9	2	126·3	172·08
23·8	3	141·6	117·52
21·8	4	153·1	89·62
19·7	5	162·3	72·66
17·8	6	170·0	61·21
15·7	7	176·9	52·94
13·6	8	182·9	46·69
11·6	9	188·3	41·79
9·6	10	193·2	37·84
7·5	11	197·8	34·63
5·5	12	202·0	31·88
3·5	13	205·9	29·57
0·0	14·7	212·0	26·36
Steam gauge pressure in lbs. per sq. in.			
0·3	15	213·0	25·85
1·3	16	216·3	24·32
2·3	17	219·4	22·96
3·3	18	222·4	21·78
4·3	19	225·2	20·70
5·3	20	228·0	19·72
6·3	21	230·5	18·84
7·3	22	233.0	18·03
8·3	23	235·5	17·26
9·3	24	237·8	16·64
10·3	25	240·1	15·99

CHAPTER VI.

QUANTITIES: BEING THE AMOUNT OF RADIATING SURFACE REQUIRED TO AFFORD WARMTH TO ROOMS AND DIFFERENT PLACES.

It is most difficult, practically impossible, to make a table of quantities, or to devise a method of calculating surface, that will be correct under all conditions. A table can be made to afford simple calculation, and to this can be added the various conditions that go to vary the figures of the table. This is the best plan for ordinary use.

To be really exact would involve very many considerations. Not only must certain figures be allowed for different thicknesses of walls, also materials and the state and exposure of the walls; but on the Continent some engineers go to the extremes of having heat losing figures for ceilings and floors of various kinds. Then there is the glass, which always needs consideration, as being the most effective heat losing material used in building construction. Then the volume of air that passes through the room per minute or hour should be calculated, for the air that goes out takes heat units out also, whilst the new air which replaces it requires heat units to make it agreeable. When all this is done the radiation calculated is only that which will give a certain temperature on a severely cold day, and the user regulates the valves to moderate the heat at other times.

It is in deciding surface quantities that the skill (which means experience), of the engineer may be displayed to most advantage. Figures and rules may be given which are reliable and necessary, but it is the engineer's judgment that adapts them correctly.

Area of Radiating Surface required to Heat Rooms and Places with Steam at about 5 lbs. pressure (ordinary type of apparatus, new or exhaust steam); or with Steam at Atmospheric Pressure or a little below, circulated by Vacuum-producing Attachment.

Rooms or Places where the Warmth may be required.	Square feet of Radiating Surface to each 1000 cubic feet of space.	Temperature obtained when 5 degrees of frost outside.
Bath rooms	12	68°
Entrance halls; also living rooms with two outside walls and full area of glass	12	63° to 65°
Living rooms with one outside wall, normal glass area. (See footnotes.)	10	63° to 65°
School rooms; offices and business places; some work rooms. With normal glass area. (See footnotes.)	8 to 9	60°
Places of worship; public halls; lecture rooms; &c. (when empty) .	7 to 8	56°
Workshops, such as cabinet-makers', watch-makers', and those having but light manual labour . .	5 to 7	52° to 55°
Drying rooms for herbs, fibres, and semi-dry goods. This temperature when empty and dry; free ventilation; little or no glass . . .	20 27 36 46	70° 75° 80° 85°
Drying rooms for very damp substances; laundry work, etc. This temperature when empty and dry; free ventilation; little or no glass .	70 90 115	100° 110° 120°

See the following notes, which modify the figures given in above table:

Notes.—Normal area of glass (windows) is approximately 25 square feet per 1000 cubic feet contents of room or place.

For area of glass exceeding the above allow 1 square foot of radiation per 12 feet of glass.

The area of glass must always be considered even when making rough and ready calculations.

The figures in above table are for "direct" radiation, meaning radiators, coils or pipes exposed in the room and not having any ventilating attachments by which the cold outer air enters and flows between their surfaces.

For "semi-direct" or "direct-indirect" or "ventilating" radiators; those standing exposed in the rooms, but having box bases connected with the outer air and having a continuous flow of air through them, add one-fourth to the areas given (this does not refer to drying-rooms).

For "indirect" radiators, these being out of sight in a case or chamber, and affording heat to a continuous air-current only, add one half to the areas given in the table.

Radiating pipes or surfaces in channels (as in church work) should be increased 15 per cent. above the figures given in the table.

Results obtained by calculating on the figures in the table can be checked by the following method of calculation :—

Allow one square foot of ordinary direct radiating surface to each 4 square feet of glass with the addition of 4 square feet of radiating surface to each 1000 cubic feet capacity of the room. This is to give 63° to 65° under ordinary conditions.

Allowance must be made for buildings in the country, or rooms in buildings which are exposed to bleak winds and winter gales.

The tables and rules relating to low pressure hot-water heating can be used for steam work, if necessary, by deducting one-third from the radiating area of the former to make it correct for the latter.

CHAPTER VII.

BOILERS.

THERE is, unfortunately, no simple rule by which the power of a boiler can be judged or fixed correctly ; there is, in fact, no rule at all, although much data is available.

In the first place, there may be a difference in the quality of the fuel, a detail over which the boiler maker and the heating engineer have no control. The suggested surface values on p. 120 are based on fuel being used capable of giving 8000 British thermal units per pound, after deducting loss and waste, and this should be possible with good quality gas coke.

The grate area controls results very materially. If too liberal it gives opportunity for the attendant to consume fuel wastefully. It makes attention of a more skilled nature necessary, although it must be added that the automatic damper and pressure regulator is very effective in preventing this trouble. If the grate area is too small it makes forced firing (quick draught) essential, with the result, always, that normal results in heat are reduced quite thirty per cent. Another fault is that with a moderate draught the air supply is insufficient for perfect combustion, and instead of the fuel being wholly converted to carbonic acid (CO_2) some proportion will be converted to carbonic oxide (CO) through shortness of oxygen. As the conversion of carbon to CO_2 can yield under good conditions 13,000 B.T.U. per pound, while its conversion to CO yields 4453 units only, it will be seen that any loss by imperfect combustion is to be condemned. CO is an inflammable gas, and may under some circumstances be consumed in the boiler, and yield its heat, but no reliance should be placed on this.

A grate area of one square foot to each 200 feet of radiation will be found to work out satisfactorily in practice with modern boilers of moderate size. As the boilers become large the proportion may be 1 to 250 and 1 to 300, allowing for a moderate draught.*

The draught or rate of combustion controls the amount of heat absorbed through heating surfaces in boilers, but it is usual to have a moderate draught and bright fire in the coldest weather. If it is desired to feed the boiler at infrequent intervals, to bank it up, then for a given surface the fuel consumed is less, the number of heat units passing to the water less, and the resulting steam proportionate. In other words, a larger surface must be allowed for a given area of radiation, meaning of course that for slow draught in the coldest weather the engineer must put in a larger boiler than the table of surface values on p. 120 would show.

Area of furnace bars includes the bars as well as the spaces between the bars. The spaces are generally about forty to forty-five per cent. of the whole.

The greatest difficulty in fixing the power of a boiler is in giving a work value to the heating surfaces. It is comparatively easy to make a table of radiating surfaces that can be allowed to direct and flue surfaces in a boiler, but the quality of these surfaces varies so greatly.

Direct heating surface is said to be that which faces the fire—that can see the fire, so to speak. Indirect surface is that which cannot see the fire because of its existing in flues or similar draught ways. The latter is of considerably less value than the former, as it depends on flame (if any) and heated gases only.

Where direct surface would differ greatly, for instance, is in a boiler having a cross section as Fig. 54. This is a purely imaginary design, like nothing made to the writer's belief, and purposely drawn so as to cast no reflection on any boiler in existence. The purpose of this drawing is to show that although it is wholly direct surface, all the interior being in sight of the fire, yet this surface could not be given much more than about half full direct surface value. All the surfaces marked with asterisks would be of lower efficacy, and this would mean that the boiler maker must give a larger surface, using more plate, for a given result, compared to boilers having no spaces for gases to gather. Anything in the nature of a confined space where gases collect or move sluggishly, or that cannot be easily cleaned, are wanting in heat absorbing efficacy. If the upper tubular portion had the smoke nozzle on it, results would be improved, but still the choked way between the tubular part and the outer crown would be of quite small value. This drawing is, of course, of a very unlikely detail of design, but it serves to illustrate the point in question. There is no grave objection to a boiler maker designing and making boilers with waste or useless space, provided he gives the space its proper low value. The real fault is that it costs him more for a given power of boiler, because he has to use more plate.

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* It is understood that all calculations are based on lowest normal outdoor temperature. As the weather moderates so does the consumption of fuel, as a certain number of the radiators would be shut off.

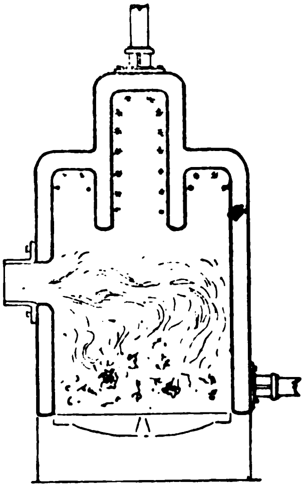

FIG. 54.

Then as to indirect or flue surfaces, these vary much more. Their size, disposition, length and shape all affect results, and it is difficult to say more than that the engineer purchasing a boiler must use judgment when making a selection or considering the illustrations. It is a final form of judgment (like deciding radiating surface), that cannot be gained from a book.

Lastly, as to indirect surfaces, manufacturers are apt to lump the whole direct and indirect together, and allow, say, 10 to 12 square feet of radiation per square foot of mixed surface, irrespective of what proportions the two kinds of boiler surface have to one another, and in the indirect is included the lower surfaces of horizontal flues, the upper surfaces of horizontal tubes and sections, dust collecting surfaces and the like, and portions of flueways not within the direct line of draught.

The modern form of self-contained boiler, having flue or indirect surface, is undoubtedly good. A plain shell independent boiler is apt to allow too much useful heat to pass into the flue. The fire must burn with a certain degree of brightness to be effective, and this necessitates a high temperature chimney if no indirect surfaces intervene. Lengthening the shell would not be so effective as the more contracted flueways, and in practice it will be found that the proportions of 70 to 30 for direct and indirect surface will work out to best economy with moderate draught. The indirect surface should not exceed this proportion very much, or general efficacy will begin to lessen with the increase. A greater area of indirect surface would be permissible if a faster draught were to be used.

Table of Work Values of Effective Heat-Receiving Surfaces in Boilers.

Direct Effective Heating Surface—	
Surface facing the fire, but not corners and recesses where gases collect . . .	One square foot to 17 square feet of radiating surface.
Indirect Effective Heating Surface—	
First flues. Flues which first receive flame or gases from the fire box . .	One square foot to 7 square feet of radiating surface.
Second flues. Flues which receive the flame or gases from the first flues . . .	One square foot to 4 square feet of radiating surface.

The bottom surfaces of horizontal flues and flue ways have some value, though scarcely worth calculating—say 1 square foot to 2 square feet of radiation. The exception to this is the bottoms of horizontal ways which lead from up-flues to drop-flues, in which case the flames or gases hug these bottom surfaces and make them equal in efficacy to the sides of horizontal flues.

The arrangement of direct and indirect surfaces governs efficacy and economy. If coke can give 8000 B.T.U. per pound consumed in one boiler (thus converting 8½ pounds of water at 212° to steam) it should give it in all, and if it does not then the fault is most likely to be with the boiler designer, as the unit giving capacity of coke does not vary to the extent of coal in its different grades. Failure may be due to badly disposed heating surfaces or imperfect combustion (making CO instead of CO_2), or it could be caused by working with too quick a draught. If a boiler had only 30 per cent. of its surface indirect with a 1 to 200 feet of radiation grate area, it would have to be worked with a moderate (or slow) draught for best results, for with a quick draught there would be too many units going into the chimney. It is assumed in all cases that the boiler is clean and working under favourable conditions.

A moderately bright fire on a square foot of grate will generate about the units that 200 feet of radiation require.

Between the fuel and the radiation, however, is the boiler, and this is where the loss of units may occur.

Boilers of small size, say under 500 feet of radiation, require a little more liberal proportion of surface than that given, but steam heating boilers are seldom used in England of less than 500 feet size.

As to the number of heat units that can be calculated per foot of heating surface this must depend on the quality of coal; also the draught, which regulates the quantity. On more than one occasion the writer has found it stated that ordinary heating boilers are made capable of absorbing over 6000 B.T.U. per foot per hour. This is abnormal, especially as mixed or average surface is meant, not wholly direct. As radiators require 300 B.T.U. per foot per hour for ordinary temperatures, this would make the boiler capable of heating twenty feet of radiation per foot of mixed heating surface. This it will not do, for it is as much if not a little more than a hot-water boiler will do with hot-water radiators, which only require to be at 180° maximum.

With moderate combustion and coke fuel the writer considers 3200 B.T.U. per mixed foot per hour as much as boilers will ordinarily transmit, which is equivalent to allowing 1 square foot of mixed surface to about 11 square feet of radiation. Very little more could be relied on with coke. American authorities only allow 2500 B.T.U. per foot of boiler surface. With best Welsh anthracite the figures could be increased, as its unit efficacy is a trifle over one-third greater than coke. Boilers with the maximum proportion of direct surface would also figure out better; though perhaps wastefully with a quick draught.

In regard to radiation per horse-power of boiler a few words should be said, for an engineer may have to buy a type of boiler, the power of which is only shown in horse-power in makers' lists. To convert these figures to radiation it is generally safe to allow 150 feet of the latter to one horse-power. This would be giving the boiler about 9 feet of mixed effective surface per 100 feet of radiation, or 13½ feet per horse-power. If it is a comparatively small boiler this allowance will fail. Box gives the following surfaces for horse-powers: 18 effective mixed square feet per nominal horse-power for boilers of 4 horse-power, 14 feet per horse-power for 10 horse-power, 12 feet per horse-power for 20 horse-power, 11 feet per horse-power for 50 horse-power.

By allowing 13½ square feet per horse-power, and 3200 B.T.U. per foot (mixed surface) we get 33,200 B.T.U. per horse-power, which agrees (nearly) with the ratio decided by the Committee of Judges at the Centennial Exhibition (America) 1876, which is 33,327 B.T.U. per nominal horse-power. These latter figures are based upon the units required to evaporate 34½ lb. of water from 212° to steam at 212° ($34\frac{1}{2} \times 966 = 33{,}327$).

A boiler made for power may be found to have a grate of smaller area than given on page 118.

It must be distinctly understood that the figures given above do not decide surface for horse-power, but give the surface that should be in the boiler per horse-power to ensure 1 horse-power being capable of heating 150 feet of radiating surface at 3 to 5 lb. pressure.

The following are essentials of construction in a steam boiler:—

1. The plan or design of construction must be such that the boiler will not "foam," this being a geyser action, a greatly disturbed state of the water at some points, inability of the steam getting released into the steam chamber freely, but projecting up water with it, probably carrying some over to the steam mains. The boiling must be effected as quietly as possible, and without commotion at the water-line.

This can only be done by having the water ways sufficiently large, and arranged so that there may be an active circulation down one and up another. A circulation will occur in a single water way if it be large enough, but for reasonably narrow ways there should be one feeding the other to some extent. Even moderately narrow horizontal waterways and a positive circulation will not ensure quiet boiling like vertical waterways. Every possible effort should be directed to getting the latter; and although it may not be possible to have all vertical in a modern self-contained boiler, the proportion of horizontal should be small and only in short lengths. Quiet steam production gives the driest steam, and it probably ensures the water having contact with the boiler plates always. When steam cannot escape freely it will sometimes lift the water from the plate, and this in course of time has a destructive effect.

2. The extent or area of water-line must be sufficient. This distinctly influences steam production, also the quiet or other manner in which it is produced. With boilers having vertical sides, the water-line should be as wide as the widest parts; that is, it should extend from outer wall to outer wall all ways at a point where the boiler is largest; with horizontal cylindrical boilers a mean width is taken. The water-line should be clear and not reduced in area by flues or tubes coming up through it; thus if a boiler were of square shape 4 feet by 3 feet inside the exterior plates, the water-line would be twelve superficial feet, not reduced or broken up. Within reasonable limits the area of water-line might be increased with advantage, if it were possible, for the freer and fuller quiet disengagement of steam. As modern boilers become more

packed with heating surfaces there will have to be means devised for increasing the water-line area, otherwise efficacy will not be proportionate to the surface put in, even supposing it is effective surface.

3. The proportions of water and steam space, the cubic space in a boiler occupied by water and that devoted to steam, must be proportionate, and are best given as 2 to 1. If the steam space be insufficient, the effective work which a boiler of given surface will do decreases in a pronounced way. No fault is experienced in making the steam space larger than the proportion given, nor is this likely to be done.

It would be supposed that the size of the steam space would not influence results if the heating surface and water-line area were full, for the natural assumption would be that if steam was wanting in the piping system it would not require any roomy accommodation in the boiler, but pass right away to its work. This, however, is not correct in practice, and a pronounced beneficial effect is had by making the steam space of the proportion given. Water space and steam space mean space actually occupied by water or steam, not including flue space.

4. Boilers must hold a sufficient volume of water so that the water when starting cold will not lower more than one inch (preferably ½ inch) when the system has been filled with steam. If there be a wet return or other water retaining space or pipe to be filled with condense water, then the water-line will go lower and must be watched; but these spaces only require filling once until they are next drained out for any purpose. This, of course, refers to a gravity apparatus, while one which discharges its condense water would have a constantly falling water-line. What it is intended to convey is that the volume of water in a boiler must not be too small, and the correct volume is that which only reduces say ½ inch in height in making sufficient steam to fill the piping and radiators, after which, with a gravity system, the boiler gets its proportion of condense water back for each volume of steam sent out.

General Notes.—Upright boilers must be limited as to height to admit of their working in low basements. It is necessary that at least 3 feet vertical height exists between water-line and horizontal supply or flow main. This is the least, and should be increased whenever possible.

If the condense water is not returned to a boiler, either by gravity, injector, or pump, and the feed water is hard (with lime in solution), there will collect an incrusted deposit of carbonate of lime—scale it is called—in the boiler. This, when of sufficient thickness against the plates, where the fire rests, will bring about a fracture—a thing much to be avoided always, for it occurs before the boiler is much worn, and the engineer generally gets blamed.

With modern heating boilers the waterway terminates level with the firebars. As the deposition of lime occurs in a kind of shower—a precipitation—it falls and collects at the lowest point. The lowest point is level with the firebars, the point where the existence of the lime can bring about the greatest injury in the shortest time. The intense heat here first causes the sediment to incrust, and this in turn keeps the water from touching the metal. When the deposit is about ½ inch thick (varying with different waters) the metal begins to quite lose the protective cooling effect of the water, and then becomes "burnt," as it is called. If it is wrought iron it generally bulges and the fissure appears in the bulge. With cast iron the leak is a little longer in coming, as there is no fibrous grain to the metal.

It is only an extremely small quantity of lime that is deposited from one charge of water, so that if the condense water is returned to the boiler it may be said that no lime deposit occurs. When the water is renewed several times a day, and this goes on for months, the deposit becomes a very real source of trouble. Whenever possible condense water should be returned to the boiler, firstly, to prevent deposit, secondly, because the water is hot, and has a valuable percentage of heat units in it.

If lime deposit must occur, the measure to be adopted to minimise the trouble and ill effect is to carry the waterway below the firebars. If the lime can be made to collect where there is little or no heat it will not harden and incrust. If it remains in grains like a fine mud, it can be "blown out," or washed out with comparative ease. This is effected by carrying the waterway down below the fire level, as the deposit, most of it, always works down to the lowest point, which, in this case, would be comparatively cool. A second effect of depositing the lime away from the fire is that neither of them are injurious to the boiler plate alone. If the lime is precipitated below fire level, it could be allowed, if desired, to collect there until it had filled the space and mounted up to the fire level, before any injury would be effected. Of course, no one allows it to collect in this way.

Unfortunately in most boilers there are places where the precipitated lime can rest and collect without going to the actual bottom, and here it brings about the destruction of the boiler plate nearly as badly as anywhere. A notable place is the ending or lowest point of the water-way over the furnace door. The deposit (if any) collects and hardens here, and a cleaning door must be placed at this point to admit of a thin chisel or edge-tool being used to chip away the incrusted lime.

A pressure regulator (a pressure-draught-combustion regulator really) should now be considered an essential adjunct to the set of fittings. This is described under Fittings.

A last detail relates to the relative heating capacities of steam and hot water heating boilers. The same size of boiler used for steam heating will heat a house by hot water, assuming the general character of the boiler makes it suitable for either purpose. The difference in the complete apparatus of either kind is that hot water has a larger radiating surface at lower temperature, some difference in the mode of piping, the same size of boiler, but, in the case of the steam boiler, having a steam space at top, which the hot water neither has nor needs.

Most American manufacturers, and some English, are making their boilers for either purpose, those for steam being different to those for hot water only in the existence of the upper steam space. Wherever there is a demand or likely to be a demand for both kinds of boilers, there is no reason why manufacturers should not make the design of one do for the other.

Where there has been a great diversity is in fixing the power of a steam boiler, although its work value as a hot water boiler is known Some go to the extreme of giving less than half the hot water radiation for steam—a hot water boiler with actual heating capacity of say 1000 feet, having 450 feet as the area of steam radiation it can deal with. Some deduct one-third from the hot water radiation, and between a third and half there are different ratios by every different maker. Some makers give much different ratios for two kinds of boilers of their own make.

This latter variation should not exist if the boiler is made on ordinarily good lines for the generation and release of steam; for if a boiler be capable of absorbing so many units for distribution from hot water radiators it is equally capable of absorbing the same number of units for steam work. If the boiler is the same size, same design, same grate area, etc., and has the same fuel and draught, all of which may be presumed to exist, it must absorb the same number of heat units. The inference, therefore, is that a recognised fixed ratio may be laid down and adhered to.

From calculation, and from the opinions and writings of other engineers of this and other countries, it is safe to say a steam boiler can be rated with 60 per cent. of the radiation of a hot water boiler of the same kind. For every 100 feet actual capacity of a boiler in hot water radiation it can be safely given 60 feet of steam radiation. This is supposing the hot water rating of the boiler is based on its being able to keep the hot water radiation at 180° in the coldest weather with moderate draught. All boilers should be capable of this, but some are not. With these latter the 60 per cent. ratio will be a failure, and one-half, viz. 50 per cent., will be more correct.

CHAPTER VIII.

RADIATORS, VALVES, FITTINGS, TUBES AND APPLIANCES.

Radiators.—Great skill is now being devoted to the radiator, to make it as perfect as possible both in heat-giving qualities and in detail of manufacture.

In the first place, the radiating surface should bear some fixed proportion to its steam capacity, and this, at present, is fixed at 2½ to 3 cubic feet of internal space to each hundred feet of prime radiating surface. This is for ordinary low-pressure steam.

By prime surface is meant that which has steam on the other side of it; any surface consisting of solid gills, ribs, feathers, or projecting parts, does not answer to this description. A solid extended part does not give off the same degree of warmth as the prime surface to which it is attached. It takes the heat from the prime surface, and, while distributing it over a larger area, dilutes it, so to speak, so that its intensity is less in proportion to the area from which it is diffused.

Radiators for steam work now have their sections joined up by metal-to-metal joints, usually taking the form of a "push" or "screw" nipple or something similar.

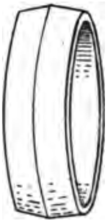

FIG. 55.

Of nipples used for this purpose there are two kinds, as stated, the "push" and the "threaded" nipple. The former is a short length of malleable iron tube, a collar, with its exterior tapered each end, as Fig. 55. The latter is a screwed nipple, much resembling the ordinary kind, except that it is tapped one end with a right-hand and the other end with a left-hand thread.

With the push nipple the joint is made by having the corresponding holes in the radiator sections turned and trued, by machinery constructed for this purpose, and the nipples are turned and prepared with equal accuracy, so that when the nipples are put in place and the sections forced together, there is a sound metal-to-metal joint made. A machine press is used to close the sections up tightly (though it can be done by hand); and bolts passing through the radiator lengthways keep the whole sound. The bolts do not usually pass through the water-ways, but between the loops. The push nipple joint is also used in jointing up sectional cast-iron boilers, and is considered to have many good qualities fitting it for this purpose. For jointing radiators, however, there is a prejudice beginning to exist, but it is founded very largely on the biassed statements of radiator makers who use the threaded nipple only.

With the screw or threaded nipple the holes in the radiator sections are tapped with a thread corresponding to that on the nipple, so that as each nipple is screwed up the pair of sections it enters are drawn together until they meet, and are thus united soundly with a water-tight joint. Originally the nipple had a hexagon shoulder or nut in the middle, as Fig. 56, and could thus be screwed up from the outside. But now this method is abandoned in favour of nipples which have internal studs, as Fig. 57, and are screwed up by a tool inserted in them. By this means the radiator sections are brought as close together as with the push nipple, and it is difficult to tell which way a radiator is put together from an ordinary examination,

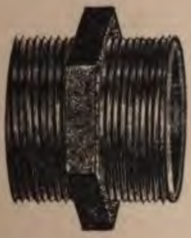

FIG. 56.

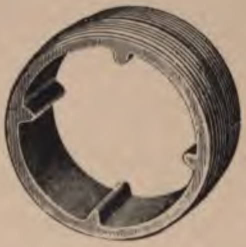

FIG. 57.

unless it is that screw-nippled radiators do not usually have bolts through them, as explained with the push-nipple method of jointing.

Of steam radiators there is a greater variety than of those made for hot water, because any hot water radiator (not having rubber joints) is suited for steam, while there are designs of steam radiators which cannot be used for hot water. All radiators which are described as having nippled joints, push or screw, will answer successfully for steam, and one of the largest firms in London importing American radiators have ceased stocking steam sections, for they find the water sections answer quite as well.

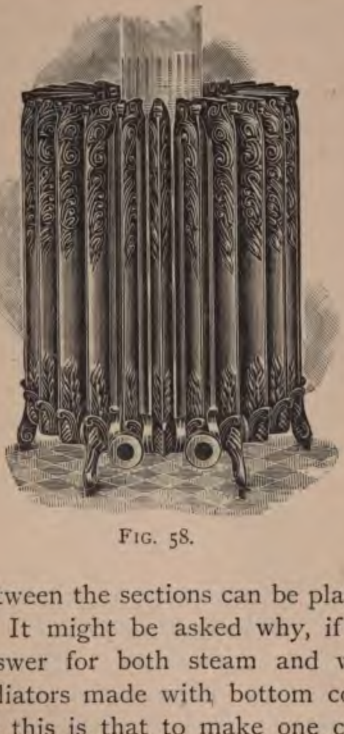

FIG. 58.

The recognised difference between steam and water sections (a number of sections forming a complete radiator) is that the former are jointed at the bottom only, while the latter are jointed at top and bottom. Fig. 58 shows a circular steam radiator, this illustration being selected as the absence of top connections between the sections can be plainly seen.

It might be asked why, if top and bottom connections answer for both steam and water, there should be steam radiators made with bottom connections only. The reason for this is that to make one connection costs distinctly less than making two, and the absence of the upper connection permits of the tops of the sections being finished much more elaborately and handsomely. The writer once bought some water radiators from seeing steam samples, and the result was quite disappointing. In this case the most important and telling detail in the ornamentation, a very finely moulded lion's head, came just where the top connection was needed and consequently it did not appear at all in the water radiators.

Another question might be asked: Why, if single connections cost less and admit of better ornamentation in the most conspicuous part of the radiator, they are not used exclusively for both water and steam. The reason is that, although steam will circulate in these single-jointed upright sections, and will also drive out the air from them, there is a doubt whether water would circulate successfully, and there is an absolute certainty of air collecting in the top of each section and stopping the water circulation, unless an air cock was put on the top of every one. This is practically impossible, for a ten-section radiator having ten air-cocks on it is out of the question.

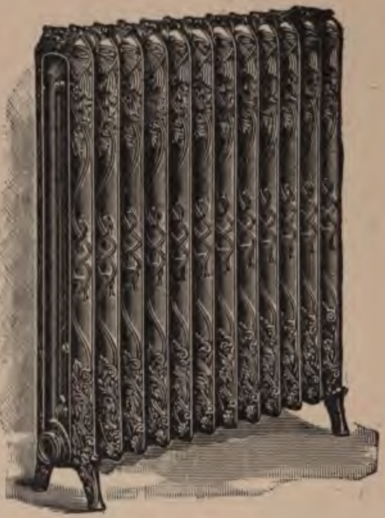

FIG. 59.

There are now so many different makes and designs of radiators, that any attempt to give illustrations of them all is impossible. It therefore remains to give a few which will serve to represent the average of them.

Fig. 59 may be described as a type of good ordinary character of radiator. It has twelve sections and is 38 inches high. As each section has a superficial surface of 4 square feet there is a total of 48 feet in this example. This pattern, like other radiators, can be had in different heights, and, of course, the number of sections required make its length.

The radiator illustrated is about 7 inches wide from front to back, and where such a width can be lessened with advantage, as in narrow corridors, what are called single-column radiators may be had. On the other hand, if the heating surface has to be increased within a given length, then the width (from front to back) is increased by giving the radiator three or four columns (tubes). Many such variations are made to meet all conditions. Curved and angle radiators can be had, also very low patterns to go under window seats; in fact the variety is now very great.

Fig. 60 illustrates the same radiator as that last illustrated, but with narrow panels slipped in between the sections front and back, these panels extending up about 18 inches. By means of these the base and lower part of the radiator are boxed in (the ends between the legs being closed also) and by bringing an air tube from the outside terminating in this base it becomes a ventilating radiator or "direct-indirect" as it is called. The air can be made to come up through a hole in the floor beneath the radiator, or it can come through an opening and a short sleeve or tube at the back. In the latter case a sufficient number of the narrow panels between the sections are lifted up a few inches to allow the air tube to

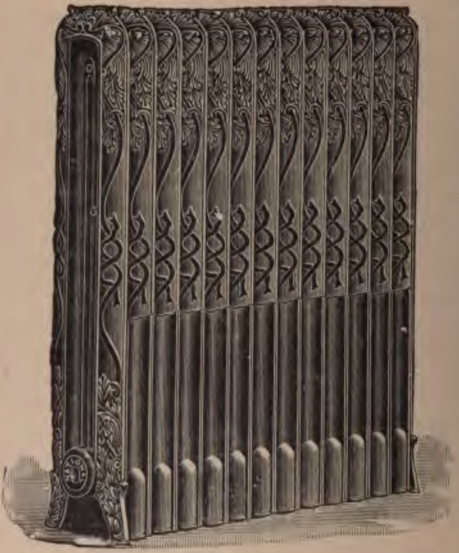

FIG. 60.

just enter the base. In both instances the inlet opening has a hit-and-miss damper over it, this being operated by a handle coming beyond the radiator at the side or end.

What may be termed the regular type of ventilating radiator is as Fig. 61. This radiator has the sections practically touching one another at the outer edges, but inside these the design of the sections makes three or four air-ways or flues, so that the air entering the base has contact—and good contact—with heated surfaces all the way up from bottom to top.

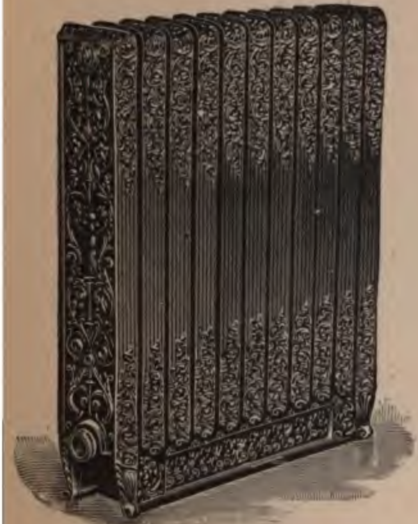

FIG. 61.

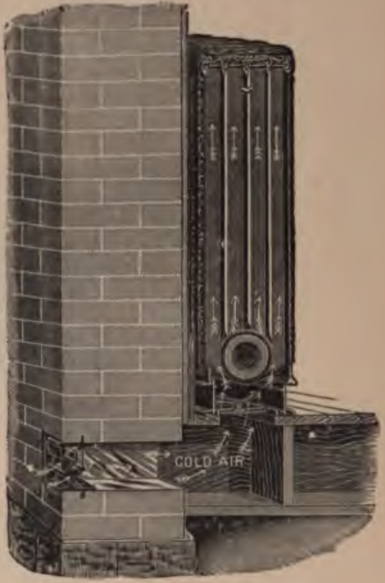

FIG. 62.

Fig. 62 illustrates this, also the base valve which regulates the air supply. The valve admits of all new air coming in, or it can be set to limit the amount of new air and re-heat some of the air of the room, or it can be quite shut. The inlet can be through the floor as shown, or it can be above the floor entering the back of the box base. The valve is easily operated by a small lever at the floor which can be moved with the foot.

Fig. 63 illustrates a type of the "indirect" radiator which is built up of sections by means of nipples like the handsomer "direct" kinds. An indirect radiator is never in sight, therefore whatever skill is devoted to its design is wholly with the object of increasing its utility and effectiveness, not its appearance. In quite the majority of indirect radiators the tubes are covered with gills, pins, or some such solid extensions of the heating surfaces and these surfaces are not, therefore, "prime," i.e. having steam immediately next to the surface. The example illustrated is listed as having fifteen square feet per section, whereas without the gills the tubes would probably have six feet of surface only.

The gills (or sometimes there are rows of pins) serve an excellent purpose, being provided expressly that the air-ways through the radiator may be narrow and tortuous, and thus most effectively warm the air which passes through. The only thing that should be borne in mind in regard to the listed heating surface is that in purchasing, the maker should be asked what area of prime surface the list figure is equal to. Quantities and figures in heating works are always based on prime surface, and extended surfaces of solid metal are not so effective. In other words, the use of gills or pins is perfectly legitimate and desirable, but they must not figure in calculations as having the heating power of prime surface.

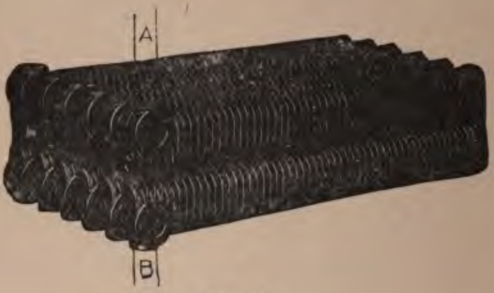

FIG. 63.

All gills and similar extensions, also the tubes of the radiator, have to be disposed so as to collect the least possible quantity of dust or dirt. Indirect radiators have to be fixed horizontally, and as a horizontal tube will have dust rest upon it, it must be designed with a view to making the quantity the least possible. Dust is composed, almost wholly, of poor conductors of heat such as vegetable fibre, cotton, hair, wool, grit (silica) and the like, all in small volume yet still retaining their poor heat-conducting qualities. A coat of dust, therefore, prevents the heat being either radiated, or abstracted by air contact and this is the opposite of what is required of the radiator. It is an important detail, for indirect radiators are not dusted daily (like the visible kind probably are) nor weekly nor monthly—yearly perhaps.

Fig. 64 shows an indirect radiator beneath a floor with cold air duct leading into its enclosure and the warmed air passing into the room. When the warm air outlet has to be

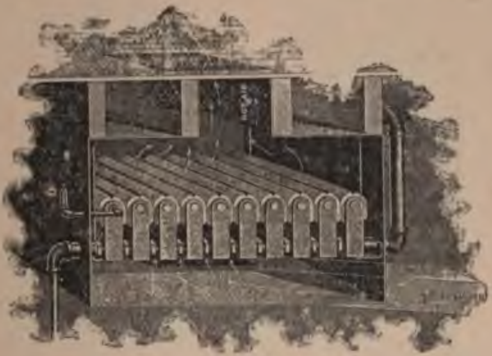

Fig. 64.

at one end or side of the radiator, the cold air must be made to enter the enclosure at the opposite end or side, to ensure the air having contact with the whole of the heating surface as far as is possible.

Indirect radiators are connected up in the same manner, with the observance of the same rules, as the others. If it be a one-pipe connection the branch rises to the radiator, so that the condense water may trickle back to the main. If it be a two-pipe connection the supply branch can rise or fall to the radiator, preferably the latter, entering at the highest connection in the radiator (if there be any difference in the level of the tappings). The return is taken from the lowest tapping and falls from thence to the main return. The air cock is put on the section furthest from the steam supply connection.

Both supply and return branches to indirect radiators are best put in of one size larger pipe than the table for direct radiator connections requires. The constant contact of new cold air makes condensation so rapid that a liberal supply of steam is necessary, whilst more accommodation for the condense water is proportionately requisite.

There are certain special forms of radiators that are suited for steam and which cannot be used for water, two examples of which are here given. Fig. 65 is a window radiator, and Fig. 66 is a design to go against stairways. They are of American make and in but small demand in England. The majority of people would consider a radiator of even height quite suited for either purpose.

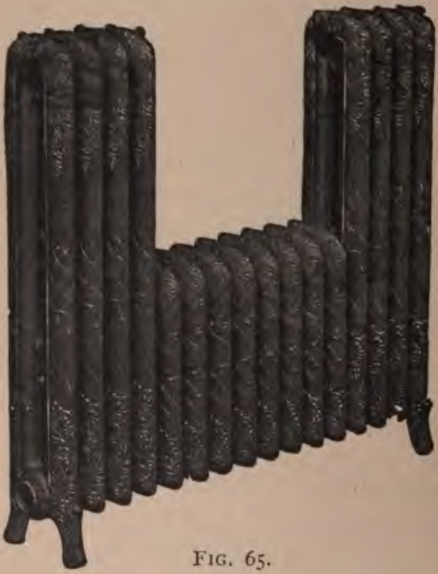

FIG. 65.

It is scarcely within the province of this book to treat of radiator designing or construction, yet something should be said as to the ultimate effect that the designing may have.

A radiator is misnamed, for although heat is radiated from it, yet the amount is small compared to the results of convection or air-warming that the radiator gives. This information however, has to be handled carefully, for, correct as it is, there is a peculiar senseless prejudice against any source of warmth that is afforded us by warming the air. The prejudice may have foundation when applied to any air-warming device which is of a sufficiently high temperature to render the air dry, or to overheat it, or to have an effect on particles of dust settling on the surfaces. Low-pressure steam can do none of these, and the air, whether pure or impure, undergoes no perceivable change in dryness, sweetness or salubrity after being warmed by these surfaces.

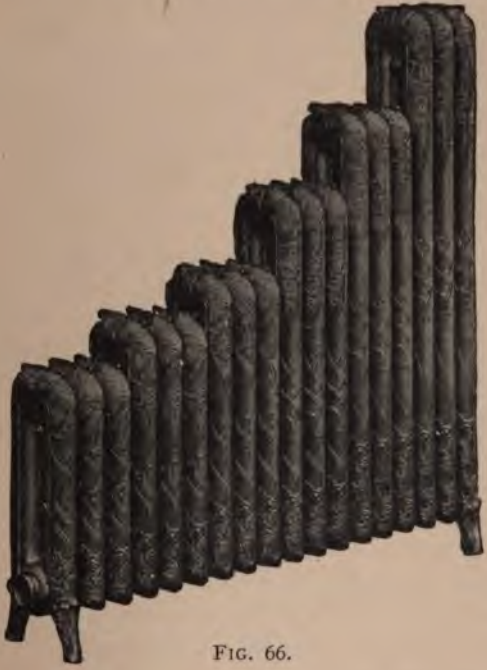

FIG. 66.

The reason for making this explanation is that the resulting efficacy of a radiator is largely, almost wholly, due to its air-heating qualities; and this in turn should have full consideration in designing, or in selecting these goods.

To test the effectiveness of a radiator a very simple experiment can be made. Take an ordinary type of sectional radiator, as Fig. 59, and surround it with boards or some carpet or stiff paper, so that its radiating effectiveness is practically eliminated. Let the covering material be well up off the floor so that air can get under and up through the sections of the radiator and escape freely at the top. If a heating test is then made it will be found that the warmth of the room is kept up as well as with the covering removed. This would make it appear as if the radiation were an absent quantity at all times, but it is not quite so. By covering all round the sides of the radiator the radiation is stopped and its heating effect lost, but the covering has converted the vertical spaces between the sections into so many flues, and the air current up through them is greater than before. In other words, the air-warming qualities have been increased by this means and so make good the loss of radiant heat.

On the other hand, if the covering material be removed and the radiator given just a plain board on top so that the upward air current is checked, the room will be found to heat at a much slower rate. The existence of the board checks air movement, and with lessened air currents there is less heat absorption. The lessened air movement greatly delays the heating of the room in those parts remote from the radiator.

To ascertain as near as possible how little work the radiant heat does, let the board remain on top and also cover the back and the two ends of the radiator down to the ground, so that the air movement is reduced as much as possible. The whole front of the radiator is left clear and exposed to distribute its radiant heat, but it will be a great time before the room heats up to an appreciable extent, and it will never reach the temperature obtained when the radiator was clear.

The experience thus gained is to avoid tops to radiators. Even grated tops are undesirable. Again, have the air spaces between the sections clear vertically, of a sufficient size, but not wide enough to prevent good air contact with the hot surfaces. All such surfaces must keep clean (or be easily kept clean).

As a final proof of the heating action of a radiator, there is one in the room now occupied by the writer, and its effect is most noticeable at two chairs which always stand in a line with the radiator across the room as Fig. 67. The room is 11 feet wide at these points. The chair marked W has a greater warmth around it than the chair marked C which has a slightly cooler air around it. The difference is two degrees. It can be distinctly felt with the hand that the air movement is like that shown in dotted lines, and this is proved by the fact that the odour from a piece of smoking paper held over the radiator is detected at W before it is at C.

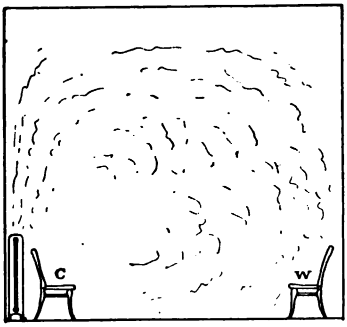

FIG. 67.

As regards the exterior ornamentation of radiators, some thought must be devoted to this. There is no disguising the fact that the introduction of prettily designed American radiators did much—very much—to stimulate steam and hot water heating in this country. Even in those places, hospitals for instance, where ornamentation is objected to on account of its gathering dust and probably objectionable organic particles, the plain radiator need not be ugly. It is quite possible to introduce a graceful effect in plain surface tubes: they need not appear a mere stack of pipes.

A final detail needing consideration is the painting of radiators. There is an unfortunate practice amongst workmen, and some of their superiors, which destroys the effect produced by the ornamentation on a radiator, by the paint they put on it. Quite the majority seem to be painted maroon, and a more unsuccessful colour could not be devised. The natural colour of the cast iron is much superior to this. Light colours and tints, or white, have much the best effect and do not get dirty at all quickly. When they do get dirty they can be washed, and no radiator should be of a certain colour expressly to disguise dirt. A body colour of very pale green picked out with apple green is good, or two shades of very pale mauve, provided of course these colours agree with the surroundings. Dark colours should be avoided, while gilded or bronzed parts have a doubtful effect.

All radiators are now constructed to afford the least possible resting places for dust. Dust is a barrier to the free distribution of heat besides being dirt in a literal sense, and dirt particles will give off an odour if heated to a high temperature.

Valves.—Of stop valves for steam work there are practically but two kinds, one form of angle valve and one straight. Both these can be had rough, polished or nickelled, with or without union, etc.

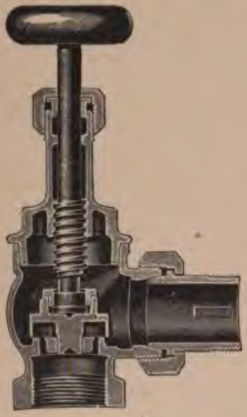

FIG. 68.

Fig. 68 illustrates in section a good make of angle valve, with union, the union end being that which enters the radiator. This valve when full open allows the steam and condense water to pass in contrary directions (if a one-pipe connection) without disturbance, provided a valve of large enough size be used. With two-pipe connections there is a valve at each end of the radiator; at the supply end the steam only passes through the valve, whilst at the return end the condense water and a little steam pass through together, both going in the same direction.

Nearly all angle valves are suited for steam work. If, however, they have composition seats then this material must be of a kind that will stand this heat. It is not every composition used for seats of hot water valves that will withstand steam temperature. The quick-opening or "Detroit" angle valve is not suited for steam because it is not steam tight. A very small hole or fissure will admit of a radiator getting hot to some extent, but will not admit of the condense water escaping. It is distinctly best to use a dead shutting valve and ascertain that it will bear steam heat.

The angle valve illustrated has an interior construction much resembling the ordinary forms of straight screw-down stop valve; that is, it has a seat which screws down on to a seating, and this, in a straight valve, makes an up-and-down way through it, as will be seen from Fig. 69. It is then known as a globe valve, and this is not suited for steam work. Whichever way round you fix them there is made a trap for condense water, unless they are fixed on their sides, i.e. horizontally. Even then the way through is very crooked and contracted and favourable to making steam and condense water come in conflict.

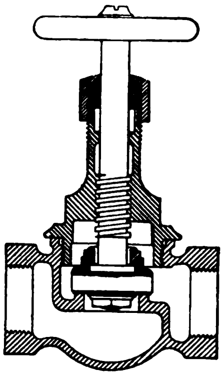

FIG. 69.

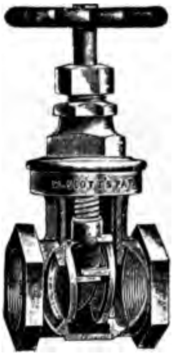

FIG. 70.

The best straight valve is the Peet's pattern, now generally known as the gate valve. This has a straight, clear and full way or bore through it and a good make will work well whichever end faces the steam and whether fixed upright, horizontal or upside-down. Fig. 70 shows a Scott's Gate valve with interior mechanism exposed. This type of valve is quite dead-shutting and steam-tight.

A novelty in radiator valves has been introduced by a well-known American maker, the idea being to make one valve serve the purpose of two on a two-pipe apparatus. This is illustrated, in section, by Fig. 71. The description issued with it says that more than this one valve is unnecessary. The single connection at the right of the illustration is the radiator union, and of the two connections at the left the upper one is the steam supply and the lower the return. An advantage claimed is a perfect circulation and a dry steam entering the radiator; also a complete circulation up to the radiator even when it is shut off. The makers also state that noise in the pipes is more effectively prevented by its use. These advantages do not sound very important except that of utilising one valve and saving labour in fitting up.

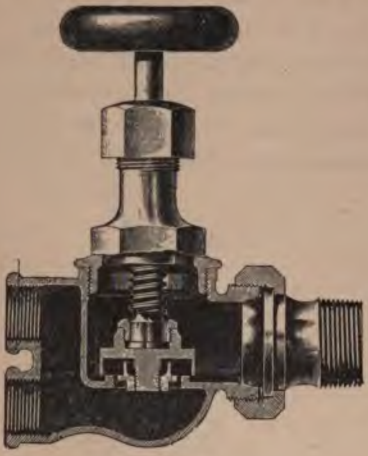

FIG. 71.

What seems to be much wanted—a want that could be easily filled by some English maker—is a radiator valve that can be opened and shut quickly. As the valves must be full open or tight shut, it is irritating to have to give the ordinary valves so many turns to obtain either result. There are quick-shutting screw-down water taps which bear a fair pressure, and no reason exists why a steam radiator valve should not be made in the same manner.

Another want is a means by which a radiator can be partially shut off so that its heat may be regulated. The nearest approach to this the writer has seen was a kind of double valve, the handle of which, when operated to open or close the valve, worked the two parts precisely alike. By this means the steam supply and the return (it was not adapted for a one-pipe apparatus) were opened and closed simultaneously, and to precisely the same extent. The maker is not known, neither does the valve appear in any of the usual catalogues. There is ample opportunity for some one to introduce these two things.

The other radiator fitting, besides the valve, is the air-vent. Air cocks are quite discarded for this work, for although they might be opened occasionally to discharge air, it is found the bell float rises or falls to close or open the outlet. It falls when there is a collection of air, as air cannot buoy it up; but as the air escapes and water follows, the float is lifted and carries the spindle up with it.

The valve illustrated at Fig. 76 is intended to overcome a fault just referred to, that of having drops of water ejected when

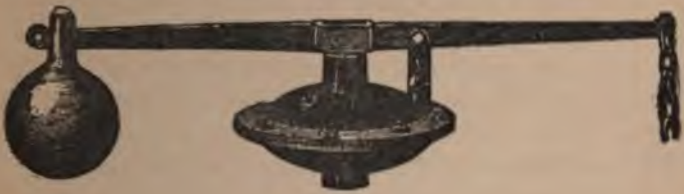

FIG. 77.

the valve operates. It is said to prevent the air and water mingling and to avoid a rattling or sizzling noise sometimes heard. The water, whatever there is, drains back into the radiator.

Of boiler fittings one of the most important is the automatic regulator. Figs. 77 and 78 illustrate this. The purpose it fulfils is a very useful one, for it automatically controls the draught, which in turn controls the fire, and this governs the steam making and pressure.

In the sectional illustration it will be seen that the dev consists of very simple parts. The actual working detail

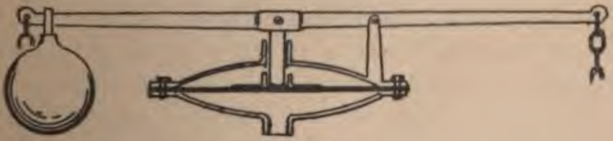

FIG. 78.

the regulator is a rubber diaphragm held between two semicircular castings, and as the pressure exerted by the steam raises the diaphragm from beneath, it lifts the plate and rod which rests on it. This rod is connected at top with the horizontal arm which operates the dampers.

As with the pressure gauge, it is correct to arrange a dip, or a method of connection that will allow of condense water only rising up against the working part, the rubber diaphragm ; for with steam heat the rubber may deteriorate.

The regulating action of this device consists in its operating the dampers so that the draught through the fuel is either hastened and a more fierce heat evolved, or it is reduced and slackened with a lessened rate of combustion and temperature. Boilers prepared for this regulator usually have two dampers,* one on the flue nozzle and one opening into the ash-pit. The former as it gradually opens allows more and more cold air to be drawn into the chimney. This reduces combustion in two ways, one the cooling of the chimney, the other depriving the fire of the proportion of air which would otherwise have been drawn through it. As this damper closes, the reverse effect is experienced, the fire increasing in brightness and heat. This is known as the " check damper."

The other damper, which opens into the ash-pit, assists in bringing about the same results, for, in closing, it gradually stops the supply of air to the fire (all furnace doors being closed) and reduces heat. By the opening of this damper the draught is made full and the fire hastened in its work. This is known as the " draught damper ; " it opens as the check damper closes, and *vice versâ.*

It is usual to have both these dampers, which do practically the same work at the same time ; but one only, if properly fitted, should do the work about as well by itself. Either one or both can be used, the preference being with both.

It will be seen that the actual work or purpose of the regulator is to increase combustion as the steam pressure falls ; or to check combustion when the fire has brought the steam pressure up to a certain point. It is quite a sensitive appliance, and will keep the pressure regular quite successfully. The weight on the arm admits of the regulator being set to keep any desired pressure. For high-pressure steam a regulator with metallic diaphragm, or a piston is used.

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* These dampers are usually doors, hinged at their upper edge (or sometimes pivoted and balanced), and their opening or closing is effected by the lifting or lowering of the chains of the regulator.

The other boiler fittings scarcely require describing, as everyone must be familiar with them. The lever safety valve, as Fig. 79, is generally used, or a dead weight. The latter, however, cannot be quite so nicely adjusted.

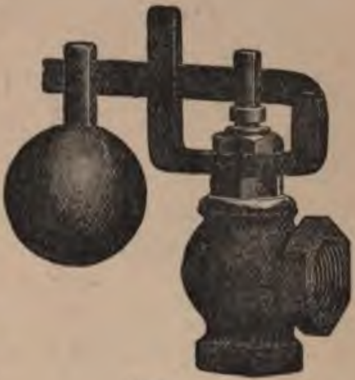

FIG. 79.

What needs consideration is the size of the safety valve, for it should bear some relative dimension to the power of the boiler in generating steam. If a steam boiler made steam faster than it could be used, and faster than the safety valve provided could discharge the surplus, there might be a rupture if no one noticed the condition of things.

It is a little difficult to decide whether the size of safety valve should be governed by the grate area or by the heating surface in the boiler. Probably the grate area is least likely to err the wrong way as regards safety, and therefore the safety valve can have its size fixed by allowing the size or area of a ¾-inch safety valve for each square foot of grate. This is for low-pressure boilers and allowing for the fact that a ¾-inch valve has not a full ¾-inch way through it when the arm lifts. It must be admitted that this size of valve would scarcely suffice if the whole of the steam made by the boiler had to pass through it. This only happens with power boilers (locomotives for example) which have the whole of their work cut off now and again, and the steam has no means of escape or of being automatically disposed of, except through the safety valve. This does not happen with heating works, and the area given will be found safe in practice, especially as the steam, as the pressure rises, will force a larger volume through a given size of aperture.

A pressure gauge is a necessary fitting on a boiler, but scarcely requiring description. Fig. 80 will, however, show its working principle, this illustrating a gauge with the dial face removed. As will be seen, the pressure or force from the boiler is exerted in a small tube bent in a nearly complete circle. The force exerted tends to straighten the curved tube and this causes the mechanism connected with the hand or pointer to be operated. Nothing could be more simple or reliable. This is the Bourdon gauge.

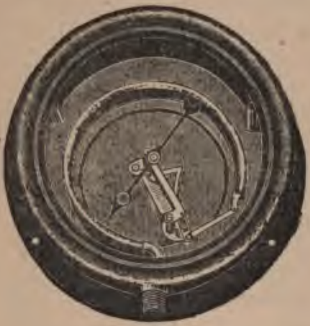
FIG. 80.

A pressure gauge should have a dip, or syphon as it is called, in the pipe which connects it with the boiler, this dip being, preferably close under the gauge. Very soon after steam is made the dip gets filled with water, after which the steam does not enter the spring tube in the gauge, only water. This ensures more reliable results, and variations in temperature do not then readily affect the mechanism.

Another important item in the boiler fittings is the water-gauge, and with this may be included the try-cocks, as they commonly figure together. Fig. 81 illustrates an ordinary water-gauge consisting of two angle valves with a tube and protecting rods between, and on the bottom angle valve, forming part of it, is a cock available for lowering the water-line if necessary. As will be known the object of the angle valves is to stop steam and water being ejected if the glass should be broken.

"Try-cocks" are merely two small cocks, either plug or screw-down, one screwed into the boiler just above water-line and one just below. As their name implies, they are to try if the water-line is at its proper place between them, it being supposed that one of the ends of the water-gauge might get choked or by some other means register falsely. The try-cocks are a check upon the water-gauge.

Fig. 82 illustrates the arrangement generally adopted in America. This is called a water-gauge column, and is shown with the trimmings or fittings complete. It is connected to the boiler by wrought pipe at top and bottom. Sometimes the top of the column is connected with the steam supply main just over the boiler, or to one of the other pipes which have free and immediate communication with the steam space in the boiler. The try-cocks are fitted to this, and as American engineers like to have a cock at the water-line, three are used as shown.

An emptying cock should be put to every boiler, either a bib-cock, or a stop-cock with pipe carried to over a gulley or drain.

A thermometer may be put on a steam boiler, this being a check on the pressure gauge and safety valve, for the temperature recorded indicates pressure, as temperature and pressure rise and fall together.

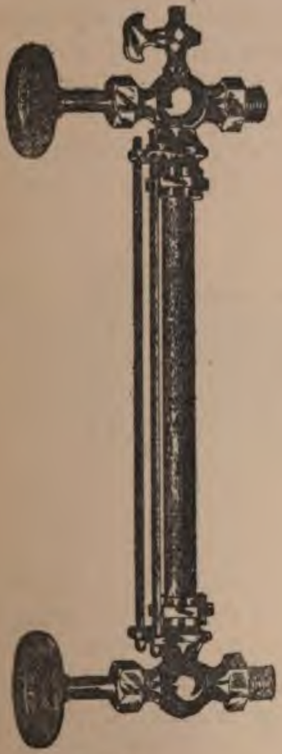

FIG. 81.

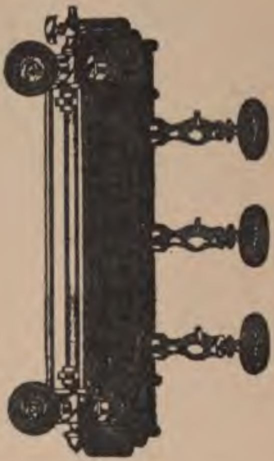

FIG. 82.

Away from the boiler and radiator there are special fittings needing description. The check-valve is described and illustrated on page 78, but an illustration of an angle check-valve, Fig. 83, can be given here. The purpose of a check-valve is to open freely for steam or water to pass one way, but to shut dead if they move in the opposite direction.

The necessity and use of expansion joints or pieces is described on page 44, and a means of obviating their use is illustrated there. Fig. 84 illustrates an ordinary gun-metal expansion joint, this consisting of a tube working within another, both carefully fitted and true, and being made finally steam tight by a stuffing box in the middle. This is made in sizes from ½ inch to 3 inches, whilst a similar joint with iron body and brass wearing parts is made up to 10 inches screwed, or 12 inches flanged.

Of steam traps to discharge condense water automatically and without loss of steam, the variety is very great. It would be quite impossible to describe all the best known, but two or three varieties may be described to show what results are attained by a trap, and how widely they can differ in mechanical detail.

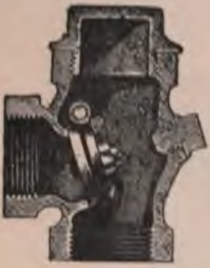

FIG. 83.

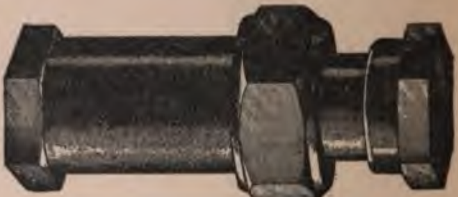

FIG. 84.

Fig. 85 illustrates a type of float or bucket trap, and the principle this acts upon is as follows:—A is the outer casing or vessel. B is the inlet to the vessel, this connection delivering the condense water from the apparatus. C is a space in which the condense water first collects. This water causes the open iron pan or bucket D to float until the water rises high enough to overflow its edges, and then as it gradually fills with water the bucket presently sinks. While the water only occupies the space outside the bucket, causing it to float, the discharge pipe E has its orifice closed by the cone (or some similar device) which is attached to the bottom of the bucket as shown. Whilst in this condition the trap is closed and is not discharging. When, however, the collection of water is such that it overflows into and sinks the bucket, then the discharge pipe is opened and the pressure of the steam forces the contents of the bucket into the pipe and from thence out. It is only the contents of the bucket that are disposed of, most of the water outside the bucket remaining, and this floats the bucket again directly it is emptied. The bucket has, of course, to be fitted with guides that it may rise and fall truly. The valve F enables the attendant to allow steam to blow through the trap to clear out the air and hasten the circulation when first heating up. This form of trap will discharge the condense water above the level of the trap to a height that is governed by the steam pressure. With a pressure of 5 lbs. the water can be driven up a pipe several feet high, which is oftentimes a great convenience. Traps which will do this are called "lifting traps."

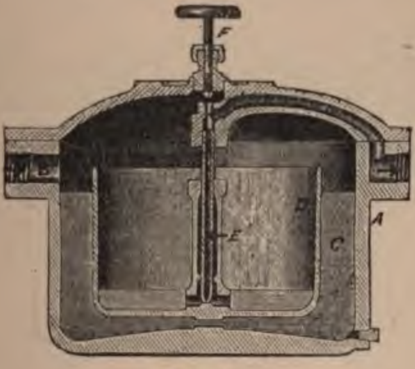

FIG. 85.

Fig. 86 illustrates another float trap, Royle's patent "Syphonia," the description of which is as follows.

The inlet for condense water is at O and the outlet at P. When first starting the box is filled with water which raises the float F and opens valve E, as indicated by the dotted lines. The cover B is then secured, and the trap is ready for use.

When steam is turned into the apparatus the condense water flows through the open valve E, following the direction of the arrows up the syphon H to the outlet. When steam arrives after the condense water, its pressure drives the water out through H, and as the water-line falls the ball F follows and partially closes the valve E. The valve, however, never quite closes, and as the condense water arrives it raises the ball again gradually, with the result that steam again exerts its full pressure on the water and ejects it as before. By lifting off the cover the ball and lever F can be thrown back, opening wide the valve E for blowing out any dirt or obstruction there may be. The valve E is the only wearing part, and this is interchangeable.

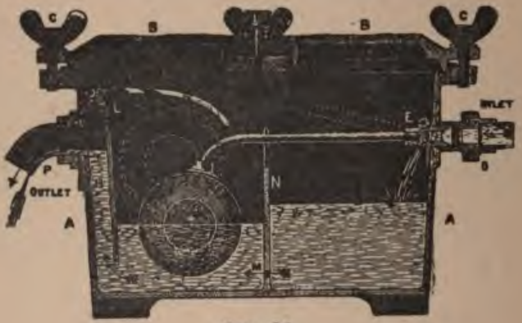

FIG. 86.

Fig. 87 illustrates quite another type, this being Holden and Brooke's " Sirius." The essential parts of this trap are the spring tube T (carrying at one extremity the valve S), and the casing B, provided with inlet (C) and outlet (D) openings. The bent spring tube T, made of finely tempered steel, is filled with a highly volatile liquid, and is extremely sensitive to changes of temperature. In proportion as the temperature rises, this liquid expands and so increases the distance between the ends of the tube until at 212° F. (the temperature at which steam appears), the valve S is pressed firmly against its seating. A is a patent renewable seating, designed to simplify the renewal of a worn valve seating.

The end of the tube furthest from the valve is held against a pivot by means of the spring E. (The spring E has no other function.) The pivot is a continuation of the regulating screw V by means of which the position of the spring tube is controlled and the trap adjusted.

The action of the trap is therefore as follows. When cold, the spring tube is contracted and the valve is withdrawn from its seating. Consequently, the trap is open full bore for blowing through all air, water and deposit when steam is first turned on, and will continue discharging until steam reaches the trap. Precisely when steam appears (i.e. when the temperature inside the trap is at 212°) the spring tube is expanded to its full extent and the valve is closed. The force of expansion is sufficient to hold the valve closed against a pressure of 200 lbs., yet the tube is so sensitive in its action that immediately the smallest degree of condensation is set up and the temperature drops (even one degree, viz. to 211° F.), the valve opens and the condensation water is blown out. As the contracting force of the tube is equally irresistible with the expanding force, it follows that this trap is quite free from the liability of sticking or failing to act.

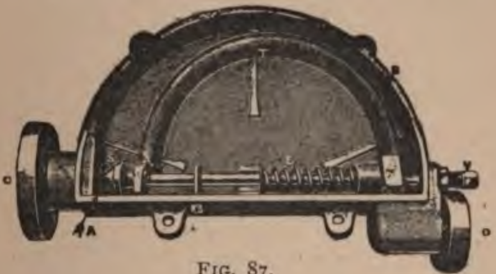

FIG. 87.

A final example can be given in Fig. 88, which illustrates Holden and Brooke's "Ogden" standard trap. This is worked by the expansion and contraction of a single straight tube. It may be regarded in the light of a spring loaded safety valve E, and the action set up by contraction simply as an easing gear, whereby under certain conditions (i.e. the presence of water), the weight put upon the valve by the spring D is eased off so as to allow the pressure in the tube to lift the valve and blow out the water. The contraction of the tube due to the presence of water causes the rod B¹ to press against and raise the lever C; at the same time, the second rod B by pressing back the lower end of the rocking arm J causes the upper end to move forward, thus doubling the action of the rod B¹ on the lever C. In addition to doubling the action of the lever C, the effect of the parallel rods B, B¹, is to equalise the strain due to contraction of the tube, and thus render the trap free from distortion and consequent deterioration.

A difference of 5° F. between the water of condensation and that of the steam will cause it to act. The moment the water is blown out of the tube steam again takes its place, the expansion once more slackens off the rods B, B¹, takes the pressure off the lever, and the spring is again free to close the valve E.

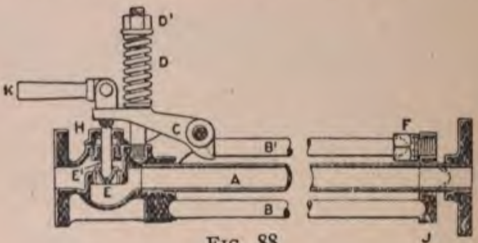

FIG. 88.

What should perhaps have been described earlier, as boiler fittings, are the means adopted to replenish a boiler with water when the condense is wasted.

With the gravity return apparatus the condense water is brought back to the boiler, and the loss is very small indeed. This is made good about once a week, and can be done when the apparatus is cold. A cold water service with a stop-cock in it suffices for this. With an apparatus, however, which discharges its condense water, or loses it by any means, the boiler requires to be fed quite frequently (depending, of course, on the rapidity of loss).

With steam at low pressures an automatic device can generally be used, much like the supply cistern, with ball valve in it, which replenishes an ordinary kitchen hot-water boiler at the side of a range. The supply cistern for a steam boiler, however, has to be a little differently constructed. Figs. 89 and 90 show the appearance and working construction

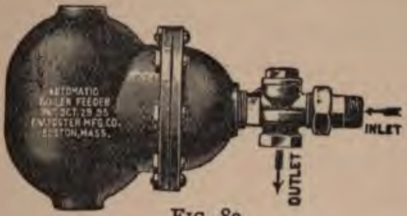

FIG. 89.

of an automatic boiler feeder that is operated by a ball float and lever, and the description which accompanies it is as follows:—

It will be seen to consist of a main valve and a small auxiliary valve. When the main and auxiliary valves are both closed the pressure in the upper part of the valve chamber, directly above the outlet, is equal to the pressure in the inlet pipe. Whenever by the falling of the float or any other means, the auxiliary valve is opened, the pressure in the upper part of the valve chamber is at once relieved and is reduced below

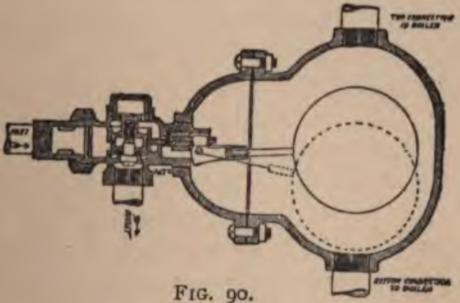

FIG. 90.

the pressure in the inlet pipe. The difference between the pressure on the upper side of the main piston and that on its under side causes the piston to be lifted to its highest position in the valve chamber, thus opening the main valv to its full capacity.

When by the closing of the float, or any other means, the auxiliary valve is closed, the water is again forced into the upper part of the valve chamber, between the piston and the body of the valve, until the pressures in the two parts of the valve chamber are equalised. The valve piston is then compelled to move downward, and the valve is closed.

The first part of this closing motion of the valve is rapid, but the latter part is made gradual by the cushioning action of the water, which is caught and entrapped in the lower part of the valve chamber. This valve contains no rubber or other diaphragm, and no springs, so that there is nothing about it that is at all likely to get out of order. It opens and closes with only a slight variation in the water-level.

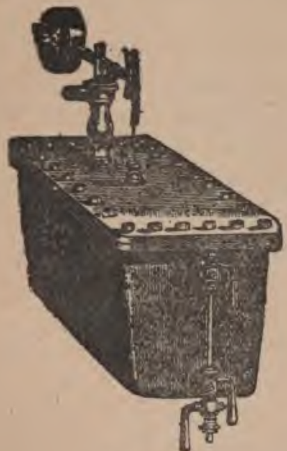

FIG. 91.

Another automatic boiler feeder operated by a float is illustrated by Fig. 91. In this case only the float is confined in the cistern or chamber, this being hung to the balanced lever above by a wire which passes through a small stuffing box as shown. The float is a slab of sandstone, as a wood or hollow metal float would not be heavy enough. The cold supply is brought to the union piece shown on the left side of the valve pillar. This pillar is hollow and conveys the water into the cistern. See also Fig. 124.

In making use of an automatic feeder it must never be forgotten that it cannot work if the pressure of water in the service connected to it be less than the steam pressure. If the boiler is to work at 5 lbs. pressure then the cold water must come from a source at least twelve to thirteen feet above, for the pressure of water in pipes is only one pound per square inch for each 2 feet 4 inches height. It is, of course, best to have the water-pressure a good pound or two in excess of the steam pressure, if possible, or as much higher as may be convenient. Water cannot enter a boiler containing steam at a pressure exceeding the pressure of the water.

The next thing to be remembered is that all such automatic feeders must be connected to the boiler by two pipes, one water, one steam; that is, one above and one below water-line. The latter is the one which supplies the water, but the steam pipe is necessary to equalise pressure in both vessels. It is just as necessary as with a water-gauge.

When the pressure of the available water is below that of the steam, and it is necessary to feed the boiler while steam is making, then an injector becomes necessary. This is seldom the case with low-pressure steam-heating apparatus, but it is desirable that the injector should appear here. Figs. 92 and 93 illustrate the appearance and the section of Holden and Brooke's "Sirius" self-acting injector. The term "self-acting," it may be explained, has an important meaning in some cases, as it means that the injector is self-adjusting to the steam pressure. In steam-heating works the pressure does not vary like it does in engine boilers. With the latter the original injector, though a much wanted appliance, had to be adjusted to every change of pressure before it would work.

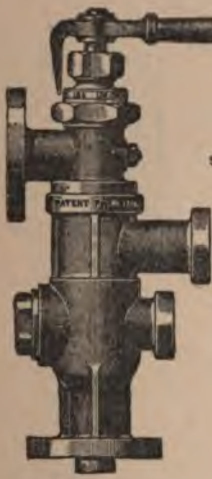

FIG. 92.

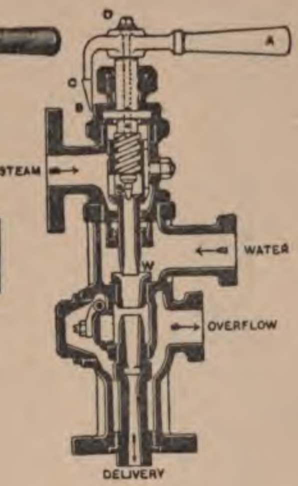

FIG. 93.

The operation of an injector is simplicity itself, for there are no working parts. There are four connections, viz., from steam chamber of boiler, to boiler below water-line, from water supply, and overflow to any point desired. To start the injector the steam is turned on, and, in the example illustrated, the steam and water cones are automatically adjusted to the pressure. As the steam rushes through, water is drawn in at the point marked W, and is carried down from thence to the delivery pipe.

Of pressure-reducing valves, for reducing high-pressure steam to any low or less pressure, automatically, there is a large variety. The principle of the valve will be seen in Fig. 44, page 88, but it is obtained in several ways. Two may be illustrated in Figs. 94 and 95. The former relies on springs; the latter has its efficacy based on the air chamber at bottom, and which gives it the title of the "air-spring" pressure regulator. Fig. 96 is a more ordinary type operated by a diaphragm and weighted lever.

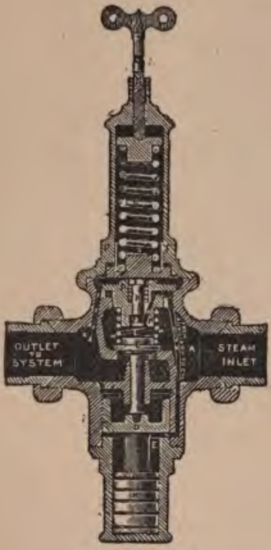

FIG. 94.

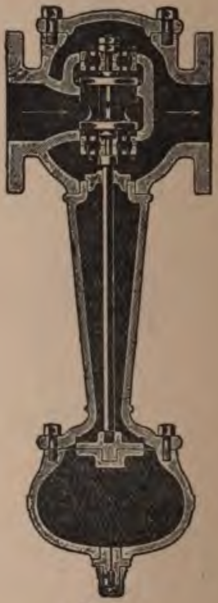

FIG. 95.

In utilising exhaust steam there are two fittings required which do not appear in the ordinary steam-heating works. One is the "back-pressure" valve, illustrated by two examples, Figs. 97 and 98. The use of this valve is not to create back-pressure but to relieve it. When exhaust steam enters a heating system it does not find a free exit, but is confined with more or less pressure. This pressure would be exerted back on to the piston of the engine if it were not relieved, and the purpose of the back-pressure valve is to do this. As will be seen, it essentially consists of a section of pipe with a door or flap in it, attached to which is a weighted lever. The weight is set to allow the flap to open at any given pressure, say 5 lbs., so that when the exhaust steam in the heating system is at greater than 5 lb. pressure, this valve relieves it, and so prevents its pressing back to the engine cylinder. See page 94.

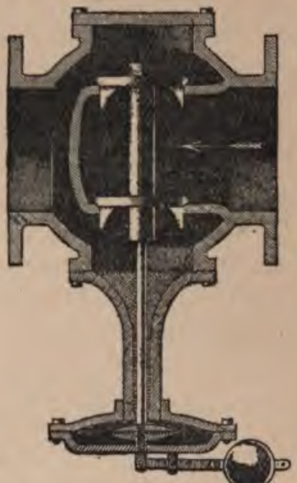

FIG. 96.

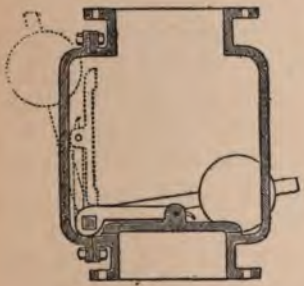

FIG. 97.

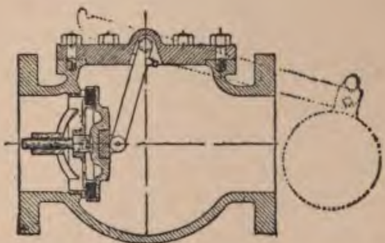

FIG. 98.

The other appliance is a "separator," the purpose of this being to separate the oil and water (but particularly the oily products) from the exhaust steam. Steam which has passed through an engine's cylinders carries oil, and should oil enter the pipes and radiators of the heating system they will soon become useless.

The principle of a separator is to cause the steam to pass over or through many irregular surfaces and ways, in doing which the particles constituting oily and watery vapours are deposited. From the bottom of the separator these liquors are discharged. An example is illustrated on page 91, and its use described on the same page. There are, however, several designs made, nearly all makers of steam fittings having them.

Of sundry fittings useful to the steam heating engineer, the eccentric reducing socket and reducing tee are particularly useful. Fig. 99 illustrates the reducing socket, and it will be noticed that the reduced opening is out of centre and level with the lower edge of the larger pipe. The good effect of this is that no condense water can collect at that point, as it would do if the small pipe came out of the centre of the larger one.

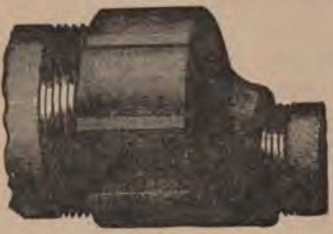

FIG. 99.

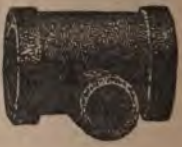

FIG. 100.

The eccentric tee has its smaller outlet in a line with the bottom of the larger pipe and drains it, as will be seen from Fig. 100. Both these fittings are occasionally useful in hot water works, to take the air from the larger pipe, but in that case the fittings are used the other way up.

The list and description of wrought-steam tube and fittings need not be given here, as every fitter is familiar with them and doubtless possesses one of a manufacturer's issue. It is, however, an opportunity of making a perpetual record of the injury manufacturers have done engineers in raising the prices (by means of a "ring") to a ruinous extent from the engineers' point of view.

Of pipe hooks and hangers, there is great variety, as makers' catalogues show. With steam work there should be free play between the pipe and the support, and, where much movement of expansion and contraction occurs, supports with rounded surfaces or with rollers, can be had. For pipes in channels a piece of ½-inch tube just laid on a piece of stone, or on the cemented top of a brick pier, will roll and give either way to the push and pull of the pipe.

Another device, in the nature of a fitting, is the Thermostat. This is an appliance which regulates the boiler fire by the heat of the house. The damper regulator is fully explained on page 145; and the thermostat is a damper regulator with adjuncts.

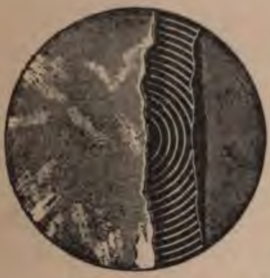

FIG. 101.

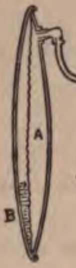

FIG. 102.

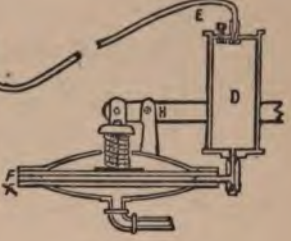

FIG. 103.

The part of the thermostat which goes in the room is here shown in a front view and in section (Figs. 101 and 102), the former showing interior construction, parts being cut away. It consists of a disc 12 inches in diameter and about 1 inch in thickness at the centre. This, when in use, is covered with an ornamental case carrying a thermometer.

It is made of heavy sheet brass, and has inside a metal diaphragm, which divides it into two separate compartments. This diaphragm is corrugated to give it elasticity, and it travels easily from one side to the other. In the compartment B, hermetically sealed, is placed a liquid which boils at 60°, forming steam in the same way that water does at 212°.

When cold, this fluid condenses and forms a partial vacuum in the chamber, and the diaphragm is forced over closely against the front or smooth wall of the thermostat by the pressure of air on the other side.

When the temperature rises above 60°, vapour (steam) forms in the chamber B, and by its expansion tends to force the diaphragm over to the other side. The force of this expansion increases with the heat at the rate of about 1 lb. for every 3°, in the same manner and under the same law that governs the production of steam in an ordinary boiler.

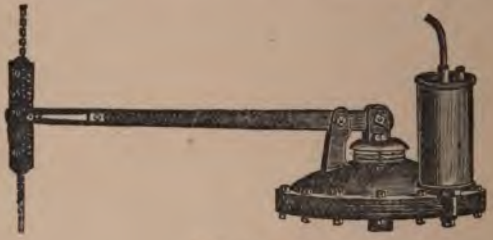

FIG. 104.

The air upon the other side of the diaphragm is forced through the small pipe causing the elastic diaphragm (F), shown in Fig. 103, to rise, and this in turn depresses the outer end of the lever, closing the damper, or valve, as the case may be.

By reference to the cut, Fig. 103, it will be seen that there are two rubbers at F, separated by a flat ring, from one side of which a projection extends that supports a brass chamber D, which is filled with water through the plug E. An opening through the ring connects the water chamber with the space between the two sheets of rubber. The water being always in contact with the rubber, prevents the air from escaping, which it would do through the pores of the rubber if dry.

The air pressure from the thermostat enters the chamber through the air pipe at the top and forces the water down and into the space between the two rubbers, raising the upper one, and with it the piston and lever, causing the damper to close.

Fig. 104 illustrates the regulator with the brass chamber D attached.

It must be borne in mind when using a thermostat, that the disc can only be placed at one point in a house or building. A point has to be chosen the heat of which will represent, as nearly as possible, the mean or normal temperature required, and the disc is fixed there. It must not be subject to draughts, nor to excess heat, as it controls the heat of the whole place and must be above giving erratic results.

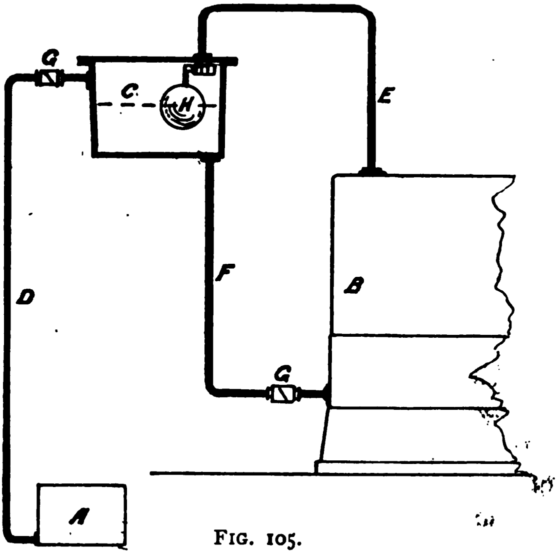

FIG. 105.

The last appliance to be referred to is a return trap, a form of trap that will return condense water to a boiler which is above the level of the tank in which the water collects ; and it is capable of returning condense water from a low-pressure heating apparatus into a high-pressure boiler while it is at work, and quite successfully. They are intended to obviate the use of pumps for delivering the water back into the boiler. The working principle can be described from Fig. 105. A is a tank into which the condense water collects ; B is the boiler ; C is the trap. A pipe D leads from the tank to the trap, the trap being above the boiler, and this pipe D it will be seen enters the trap above the general water-line. A steam pipe E is carried from boiler to trap, and a water delivery pipe F runs from the trap to boiler. G G are check-valves arranged to allow of a flow of water in the direction of the boiler and not from it.

If steam be first allowed to pass into the trap by the pipe E, and there condense (as it will do) to form a vacuum, water will be carried up from the tank A into the trap. When it reaches a certain level the float H is lifted and opens a steam valve connected with pipe E. This permits steam from the boiler to enter the trap, and the pressure in both boiler and trap is alike. When this occurs there is nothing to prevent the water in the trap passing, by its own weight, down the delivery pipe F into the boiler, until the float H falls again and closes the steam inlet to the trap. The steam left in the trap now condenses, and this brings up a new supply of water from the tank A, and the process is repeated.

Although not a fitting or appliance connected with steam boilers, this chapter would not be complete without reference to the " Steam loop." It is a means of automatically delivering condense water into a boiler from a point below the boiler level. It is but little used as yet, but no one has uttered a word of condemnation, and it would appear as if the idea had a great future. The steam loop is said to be suited for lifting condense water (from a heating apparatus) drained into a tank below the boiler level and, although the writer has not done this nor seen it done, it seems quite possible.

Fig. 106 will show the method of making a steam loop, and will serve to describe its action. The boiler will be seen on the right, a steam supply main leaving its top as usual. It is supposed in this instance that the supply main has to drop below the water level, then rise to a fair amount of work, so that condense water gathers at B in some volume. In the ordinary way it would be discharged by a trap, but in this case the steam loop is used to carry it back into the boiler. It may be here mentioned that no check or stop valves are needed in the loop to make it act: they are only put in when the fitter considers they will serve some special purpose.

From the point B, where the water collects, a connection is made and the riser C taken up in the manner shown. This riser can be any size from ¾ to 2 inches, according to the amount of water to be dealt with. At a required height (which will be understood directly), this riser dips down and is connected to a larger sized horizontal pipe D. If the riser was 1½ inch pipe, the horizontal could be 2½ inches. From the horizontal a drop-pipe, or drop-leg, is carried down to boiler and enters below the water-line. This is all there is of the steam loop—merely some 30 feet of pipe and fittings.

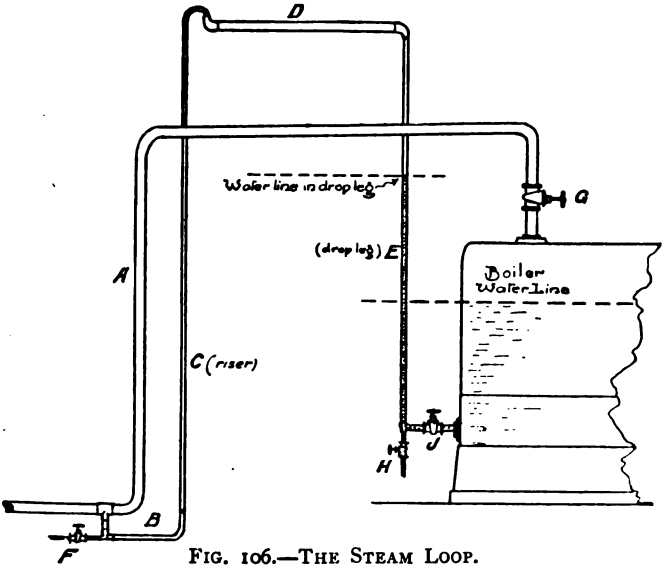

FIG. 106.—THE STEAM LOOP.

Supposing the pressure in the boiler was 20 lb. and the pressure at B 18 lb., then the water column in drop leg E would rise nearly 5 feet* to obtain a balance of pressure, an equilibrium in the loop. The equilibrium, however, is constantly being disturbed by the fact that steam condenses in the riser

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* The pressure or weight of water in pipes is 1 lb. per square inch for every 2 feet 4 inches in height.

C and particularly in the horizontal D, tending to make a vacuum, and exerting a pull on the contents of the two vertical pipes. The pull is equal on both pipes, and were their contents the same, the apparatus would fail, but in one pipe is steam and in the other water, and the steam fills the space every time, as fast as the condensing steam makes the vacancy.

The consequence of this is, that the quick flow of steam up the riser carries the condense water with it as a spray or scud, and the action seen through a section of glass tube (in the riser of a practical loop) gave the appearance of an irregular rain of water, which, however rained upwards instead of downwards. It simply resolves itself into the question as to which of the two vertical pipes of the loop can fill the horizontal D first when a vacuum occurs, and it is found that steam in the riser, although carrying water, is much quicker than the solid column of water in the drop-leg. Of course, once the water is in D it trickles down the drop-leg to the boiler.

It is considered that D should be of reasonably limited length, or should it be very long a part had best be covered. It is only needed to condense just sufficient steam to give the lifting effect required in the riser. It is also considered desirable to put the reducing fitting of the drop-leg on the horizontal side of the elbow, so that a certain amount of water is trapped along the bottom of D; this is done with the idea of accelerating condensation of the arriving steam, but it is not really necessary. This is not shown in Fig. 106, only a reducing elbow being used so that D drains quite empty.

The various valves shown are provided to start the loop working thus. When starting, open valve F, then turn on steam by valve G and keep F open until live steam blows through. Now close F, open H and blow through in the same manner, then close H. The loop is now clear of air and water, and contains steam only. By now opening J the water will rise up the drop-leg to its normal height, and the loop should work perfectly as long as there is steam to work it.

CHAPTER IX.

HEATING WATER BY STEAM.

THERE is very little useful data to be had relating to the heating of water by steam. It is work that has an extensive field of usefulness, for where there is a sufficiency of steam power it is unnecessary to have a separate fire to heat water, and, as everyone knows, hot water is needed in most all places and for many purposes. A hot water heating system can be heated by a steam heater in a much better manner than by a fire; that is, with less fluctuations of temperature and with less trouble and attention. It is also economical when there is steam to spare. For the supply of hot water at taps, steam is equally efficient; also for furnishing boiling water for any purpose. Where there is exhaust steam to be had, water can be heated almost free of cost (*see* Heating by Exhaust Steam).

An ingenious method has been devised for heating water by steam for draw-off purposes, consisting essentially of two taps attached to a mixing chamber which has an ordinary tap nozzle. One tap when opened supplies steam, the other cold water, these mixing in the chamber. By this means the cold water is heated, and that issuing from the nozzle is of a temperature according to how the steam and cold water cocks are adjusted.

Fig. 107 illustrates the "Stott" patent instantaneous and silent water heater.* As will be seen, the upper valve and connection is for steam whilst the lower horizontal one is for water. The issuing water comes from the nozzle below.† By regulating the valves the temperature of the water can be made just whatever is required, and the issuing water will be this temperature for as long as the valves are left so.

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* J. Stott and Co., Oldham.

† It will be noticed that this combined tap will, by operating the valves, supply either cold water, hot water (any heat) or steam. Only the one draw-off

If required the volumes of steam and water can be arranged so that the issuing water is actually at boiling point. This is useful for tea making on a large scale, as at institutions, also for sterilising and many purposes.

On the other hand the device is very useful for furnishing large volumes of water at a less temperature, as required for baths, and the temperature will not be uncertain. It seems to have solved what is almost a problem with swimming baths, viz. how to have them filled with warmed water quickly, how to keep it at a constant temperature although new water may be continually flowing in, how to do this with little expense of apparatus and absolutely free from danger or annoyance to the bathers. Of course all these good features, to be had by the use of the heater, appear to less advantage when there is no steam to be had from an existing boiler; though, considering

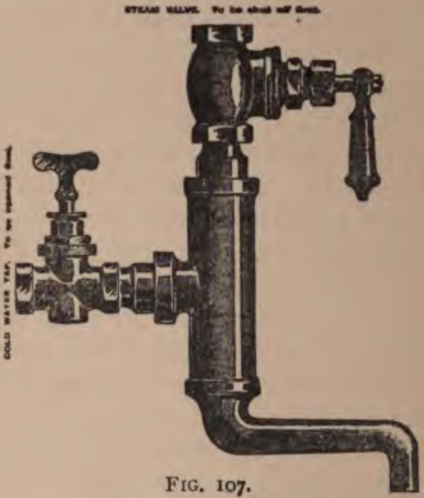
STEAM VALVE. To be shut off first.
COLD WATER TAP. To be opened first.

FIG. 107.

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is therefore needed at wash-tubs and the many places at which both hot and cold taps are otherwise required. With washing machines a supply of steam is sometimes needed; the tap provides this also.

the actual aggregate gain it would be as well to put in a steam boiler instead of one for heating water only, for this purpose, provided a competent man attended to it afterwards and properly watched the water-gauge.

The makers of the heater, Fig. 107, also make it with locking keys or levers as Fig. 108, which regulate the proportionate volumes of steam and water, so that scalding is impossible should the taps be used by elderly inmates of unions or infirmaries, etc. This heater does not yield water hotter than 110°, although it would act like the other if ordinary keys were put to the valves.

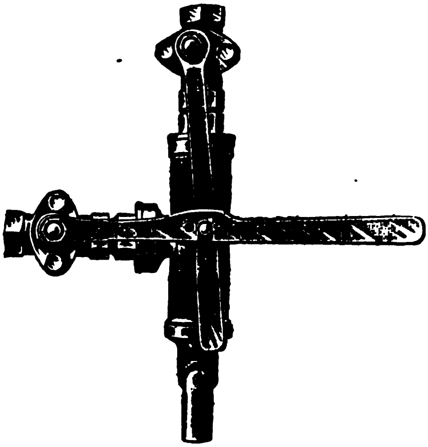

Fig. 108.

It will be noticed that the title of this appliance includes the word "silent." Water heaters which rely for their heat on free steam * do not always act noiselessly by any means. When steam enters a body of cold water it first makes a place for itself, then condenses, and this is all done in an instant. The water has, in a sense, a space always opening and shutting, with the result that, as water is incompressible, there is a sharp shock or blow delivered each time. The noise, when it is

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* This is when the steam and the water mingle, not being separated by a thickness of metal as they are in the different forms of tubular heaters.

made, is a loud and sharp crackling, or like a series of feeble musket shots delivered irregularly. It is loud enough to be unbearable as a rule. This heater, however, is noiseless.

As to the amount of steam used by this means the calculation is very easy. The steam has 966 units per pound over boiling temperature; that is, it has 966 B.T.U. to dispose of in heating cold water. Its condense water is then 212°, but the quantity is so small that it may be ignored in the calculation. To heat a pound of water from say 50° to 110° requires 60 B.T.U., so that one pound of steam is capable of heating 16 lbs. of water (1·6 or $1\frac{5}{8}$ gals.)* to this extent. It only remains to be ascertained how much water may be required per day, and its temperature; then see if the boiler is capable of furnishing the steam over and above its ordinary work supply.

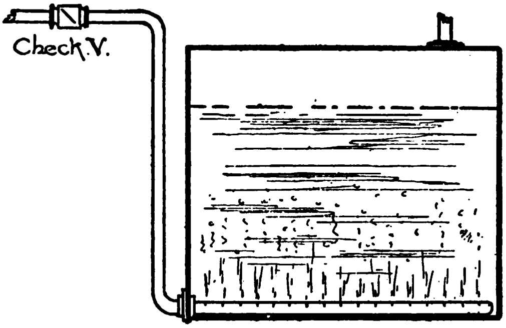

FIG. 109.

Another method of heating water by the direct injection of steam. The method most commonly adopted is to let the steam come freely into a body of water in a tank. A steam service is simply brought to a tank, or whatever other receptacle holds the water, and connected at a low point. The connection may be in the side of the tank, as Fig. 109, or it can come through the top of the tank and drop down inside. In either case there are two rules to be observed. One is to let the steam enter as near the bottom as possible, for the source of heat must always be at the bottom of any vessel intended to heat water; the second is that the steam supply must rise to above the water-level in the tank before it drops to the latter. This is to prevent the contents of the tank running down the steam supply pipe when steam is not coming up it.

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* A gallon of water weighs 10 lbs.

It is, of course, always necessary to have a stop valve in the steam supply pipe, and this must always be closed when steam ceases to be made. If it is left open a vacuum will be formed, and this will syphon the contents of the tank over to the boiler, assuming the boiler is below the tank. If there is doubt about the cock being closed, a check valve must be used.

This mode of heating water by steam is as effective as the last in quickness and general efficacy, being much quicker than any method in which the steam and water are separated (the steam in a coil for instance). But opposed to this there is one disadvantage, the noise, great enough in most cases to make the method unsuited for practical purposes. The rumbling and cracking is unbearable if the tank is in a kitchen, laundry or any place where people are at work or otherwise engaged.

To obviate the noise there have been introduced what are usually called "silencers," or some name having the same meaning. The first of these consisted of a perforated box or case containing bullets, the idea being to break up the direct current of steam and let it associate with the water less vigorously. The writer has never used one, but from general information gathered this plan was no more than a very limited success.

The more recent designs are of the character of an ejector, a steam nozzle projecting just into the end of a tube, and space around the nozzle for water to be drawn into the tube by the rush of steam. There is then an ejection of heated water, with perhaps a little steam, from the further end of the tube, as will be seen by Fig. 110. They are not always absolutely noiseless. Much depends on the pressure of steam and adjustment of the steam supply.

It should be noted that in all cases where water is heated by free steam, the bulk of water is increased by the water made by the steam as it condenses. This latter volume is not large, but with a very full tank it might cause an overflow, and there are many instances in which this detail has to be considered and provided for.

With this mode of heating water, as with the last described, the calculation for the amount of steam needed is quite easy. As explained on page 26 the steam has 966 heat units per pound to dispose of, and water requires one unit to raise each pound of its volume one degree. To heat water from say 50° to 110° requires 60 units per pound, and there are 10 lbs. of water to the gallon. One pound of steam would therefore heat 1·6 or $1\frac{5}{8}$ gallons from 50° to 110°.

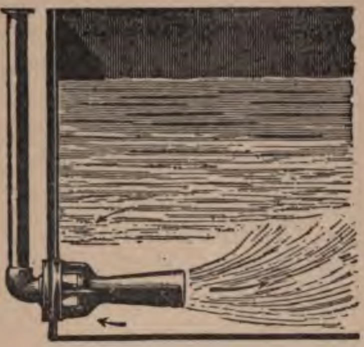

FIG. 110.

To illustrate the method of calculation when steam is discharged directly into the water, a case that was proposed for solution may be taken.

A tank contains 1000 gallons of water, which has to be heated from 82° to 170° by means of exhaust steam. The exhaust steam delivery pipe is 5 inches diameter, and the initial pressure of the steam 5 lbs. per square inch above atmosphere. No other data are given, and we will assume that the pressure of the steam is one pound above the water pressure at the end of the pipe where the steam is delivered at the bottom of the tank, also that the available volume of steam is sufficient to make the flow constant under these conditions.

First may be found the weight of the water to be heated. A gallon of water weighs 10 lbs.; and hence 1000 gallons will weigh 10,000 lbs. Each pound is to be raised from 82° to 170°, so that for each pound we shall require 170 − 82 = 88 heat units. To heat the whole 10,000 lbs. we shall therefore require 10,000 × 88 = 880,000 heat units. Now one pound of steam will give out 966 units of heat in condensing into water at 212°, and 86 units more in cooling to 126° (which is the average temperature of the water in the tank).

As there is an unknown amount of heat being continuously radiated from the tank into the surrounding air, no account need be taken of the heat given out by the condensed steam in cooling from water at 212° to water 126°, as this will roughly compensate for the loss by radiation. In other words, allow only 966 units of heat for each pound of steam condensed, as the amount actually available for raising the temperature of the water in the tank. So that to obtain the required 880,000 heat units we should have to condense

$$880{,}000 \div 966 = 911 \text{ lbs. of steam.}$$

Having found the number of pounds of steam that would be required to heat the water to the desired temperature, it can be found how long a time would be required for the supply pipe to deliver that quantity of steam, under the given conditions. This is an uncertain element in the calculation; and its uncertainty is due to the fact that the discharge from a steam pipe is largely influenced by the length of the pipe and the number of elbows and valves it contains. A straight 5-inch pipe, 100 feet long, may be expected to deliver about 77 lbs. of steam per minute, under the conditions which are assumed, and this may be taken as the actual discharge of the pipe in question. If 77 lbs. are discharged in one minute, the time required to discharge the 911 lbs. will be

$$911 \div 77 = 12 \text{ minutes.}$$

This calculation assumes that the steam available for the purpose of heating is sufficient in volume to maintain a steady flow through a 5-inch pipe, under an initial pressure that is constantly one pound greater than the pressure of the water in the tank at the discharge end of the steam pipe. If this condition is not fulfilled, the actual time required may be much greater; and the difference, in extreme cases, may amount to an hour or more, so that the calculation, at first thought, may appear false and unreliable.

It takes a large amount of heat to raise the temperature of half a ton of water through 80 or 90°. We have seen that we should have to use 77 lbs. of steam every minute, in order to raise the temperature of 10,000 lbs. of water from 82° up to 170° in twelve minutes. This is at the rate of 77 × 60 = 4620 lbs. of steam per hour. Allowing 30 lbs. per hour as the equivalent of a horse-power, there would have to be boiler capacity of at least 4620 ÷ 30 = 154 horse-power.

With a smaller boiler capacity it would be impossible to do the heating in so short a time as twelve minutes, because it would be impossible to keep up the assumed flow of steam through the 5-inch pipe. A 50 horse-power boiler having about one-third of the capacity required to do the work in twelve minutes, might be able to do it in 3 × 12 = 36 minutes, though the loss by radiation from the tank would be much greater in thirty-six minutes than it would be in twelve minutes; and therefore some further allowance would have to be made on this account. A 25 horse-power boiler would have about one-sixth the capacity, and hence, if there were no extra radiation, it might do the work in 6 × 12 = 72 minutes, or something over an hour. But when the process is carried out as slowly as this, the radiation of heat from the tank would be so considerable that a materially longer time than the calculated hour and twelve minutes would be required, in order to compensate for it.

Exhaust steam is used very largely for heating water tanks such as described, and as the volume of the exhaust is often insufficient to maintain a flow of steam sufficient to effect the heating in the time desired, it is advisable to provide some means of drawing enough live steam from the boiler to supplement the exhaust and keep the flow up to the necessary volume. An arrangement of this kind is easily made. The exhaust from the engine passes through an oil separator, to remove such oily vapour as it may contain.* A side pipe from the live steam main then enters it, after passing through a reducing valve which is set so as to open automatically whenever the pressure in the exhaust pipe falls below the point at which the required flow of steam is obtained.

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* The water would be tainted with oil a little, however perfectly the separator might act.

An ingenious, and what promises to be an excellent method of heating the water of a hot water circulating apparatus by steam (when it is decided to heat this water by steam and not by a hot-water boiler) is by the utilisation of an injector. This method is quite new to most people, and it has good features when it is applicable.

Probably the first public notice given this method of heating was by a paper read before the Institution of Heating and Ventilating Engineers.* In this the results of a practical test with an apparatus recently erected were given. The author stated that a hot-water heating apparatus having 4000 feet of radiating surface was kept at 200° by 400 lbs. of steam per hour, and that in addition to ordinary methods adopted to determine the figures with accuracy, the condense water was also measured, and it confirmed the calculations.

The figures, however, do not agree with theoretical calculations, for hot-water radiating surfaces at 200° give out about 250 heat units per square foot per hour (according to the temperature of the air), and this number multiplied by 4000 gives exactly 1,000,000 units from 400 lbs. of steam. As steam has barely a thousand units per pound to dispose of it would appear as if the volume of steam should be a little more than doubled. The author's word, however, is not one to be doubted, and it must be assumed that during the test the conditions varied in some way ; and if the aggregate result was satisfactory it goes to prove that the method is a very economical and good one. The steam used represents about 40 lbs. of good coal (anthracite or good hard steam) per hour to heat the whole of a building which would have about 350,000 cubic feet of space in it.

It is to be feared that a mistake was made somewhere. Possibly the temperature of the water fell (due to the steam supply fluctuating by the varying demands made upon it by engines, etc.), in which case the figures quickly come nearer to agreeing with theoretical calculations. This can be judged by the rapid way the heat loss reduces as the heat of the radiating surface goes down. With the surface at 170° for instance, the heat units diffused are only about 185 (varying with the temperature of the air) instead of the 250 units from the 200° surface.

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* By W. R. Maguire, J.P., of Dublin.

Fig. 111* illustrates the injector used by the author of the paper just quoted. The steam supply is connected where marked, the return pipe is connected to the opening marked "water," and the flow-pipe to the opening marked "delivery." This injector gives no trouble in use, as it is self-acting and self-adjusting to pressure, whilst being operated by a single movement.

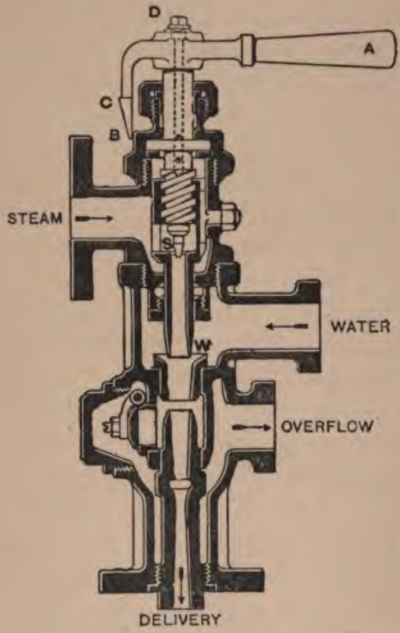

FIG. 111.

When fitted up, the water in the heating apparatus is heated by the injection of the free steam, and the temperature of the water is governed by the amount of steam that is allowed to pass in. Once the handle is placed where desired, the heat of the water remains constant, without fluctuation, unless the volume and pressure of steam vary. The steam supply may be taken off a service which goes to fulfil many requirements. It may have engines on it; if in an institution it may serve laundries, cooking vessels, heat water for domestic uses and baths, etc. A steam pipe, if not full large, must give a fluctuating supply as these wants are supplied or shut off. This is mentioned

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[*] Pattern S injector by Holden and Brooke, of Manchester. It is noiseless in action.

because it so commonly happens that an existing steam service is tapped for the new work, without properly realising what amount of steam is required beyond that which the pipe was originally provided to supply.

There would be no gain whatever, but quite the reverse, in fitting up a steam boiler expressly to heat the water of a hot-water apparatus in this manner; but where steam is to be had and spared from an existing boiler the method can be adopted. What is claimed in the way of advantage for this system is the small cost of the heating appliance—the injector—compared to a tubular steam heater or a hot-water boiler. Further the circulation is made more positive under unfavourable or any conditions, as the steam is an element of force and impels the water along the flow pipe by its jet. This movement is in addition to the ordinary circulation due to the difference in temperature and weight of the flow and return waters. This propelling effect is a gain when the conditions are unfavourable to a free natural circulation. If the pipes are dipped, wanting in sufficient rise, inclined to have air collect along the horizontal parts, or pipes somewhat small for the work, then the force of the steam is a real gain.

It is a method that can be adopted with quite new and properly erected hot-water circulations, but is particularly serviceable when there are certain faults. It can be used as an auxiliary to an existing boiler or heater which is under power. It is not necessary to remove an existing boiler or heater, as the injector can be connected up to the mains independently.

It will be seen that the use of an injector in this manner causes an increase in the bulk of the water in the hot-water apparatus, owing to the steam which is injected making a certain amount of condense water. For instance, the 400 lbs. of steam mentioned in an earlier part of this chapter would add 40 gallons of water to the apparatus per hour.

Provision has to be made for this, in the nature of an overflow pipe. The overflow water can be conducted back to the boiler and injected, or otherwise used as hot feed water. It is best to have the injector in the boiler-house if possible, so that it may be attended to and regulated easily. If left open when steam goes down the water will pass back along the steam supply pipe, and a check-valve must be provided to prevent this in addition to the usual stop-valve. The steam pressure must exceed the water pressure, of course—it can scarcely ever happen otherwise, unless by chance a service was tapped which only conveyed steam at reduced or low pressure. As a rule, the steam is seldom less than 30 lbs. in institution or hotel work and the like.

This practically ends the description of apparatus for heating water by free steam, and there remains to be explained the heating of water by steam in heaters.

What are known as steam heaters * are generally well made and strong cylindrical tanks containing a number of tubes or a coil; the steam is generally inside the tubes or coil and the water outside them. Figs. 112 and 113 illustrate the two kinds, but there are varieties of each—some differences in the arrangement of the tubes or coil.

It is not always desirable to let the steam pass through inside the tubes, as the first illustration shows, for it must be remembered that steam is quickly condensed on contact with cold surfaces. The consequence of this is that, given a small size of tube, and this surrounded with cold or cool water, the steam may cease to exist as such after it has entered one or two feet. There would be steam in this length of the tubes, but the remaining length of them would be only acting as draining pipes for the condense water. Under these conditions a 4-feet heater would only do the work of, say, a 2-feet heater, while the water was cold. After the water had eventually got hot it might be that the whole 4 feet length of the tubes would have steam through them, but not before.

A common size for the tubes is 1½ inches external diameter—a good size for certain lengths, but it is impossible for one size of tube to be correct for all lengths. Long heaters with small tubes must necessarily be very slow in first heating because the steam does not get through, as just explained.

The best plan is to have the heaters as short as possible, or, whenever a greater length than 3 feet is required, to let the

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* Also called calorifiers.

steam enter the shell and surround the tubes instead of passing through them. By adopting this latter plan the heater is made as efficient at the first moment of heating up as when all is hot later. One special recommendation, however, is necessary, this being that with water inside the tubes the heaters should always be fixed upright, or else given a very decided tilt, to induce a free and rapid circulation through the tubes.

Fig. 112 is a horizontal heater, showing the different connections. With the connections arranged in this manner the heater might be used in a vertical position if desired, and the vertical is the best position whenever it can be arranged. Practically all manufacturers show this heater with the flanges for horizontal fixing only, as if this were the best and correct way of placing the heater. Probably the space at command makes horizontal fixing very common, which accounts for the practice; but vertical fixing affords distinctly superior results.

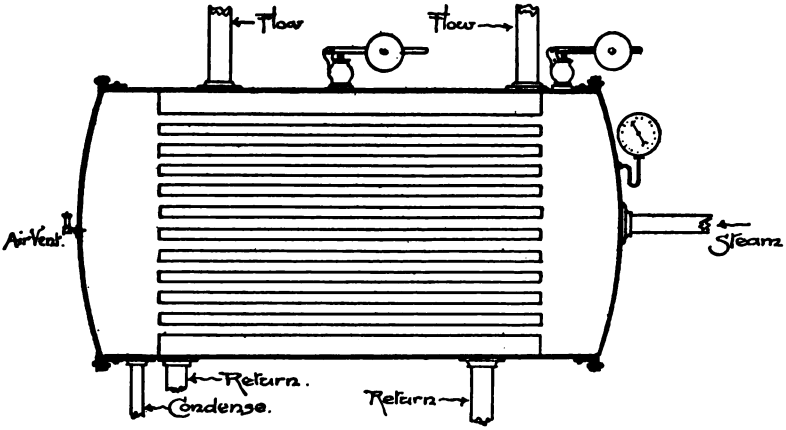

FIG. 112.

If the heater must be placed horizontally, then it should be tilted as much as possible with the steam inlet end highest.

There should be, properly speaking, two safety valves on a heater, one to the water space, and one to the steam. All water heaters which may have their contents boil should have a safety-valve. The steam chamber of this heater needs a safety-valve if the steam boiler is worked at a very high pressure and the steam is reduced to the heater. The necessity for the safety valve would arise if the pressure reducing valve got out of order and failed to reduce pressure.

A pressure gauge should be put on the steam space, as otherwise there can be no certainty of what steam the heater is getting, when its supply is branched from some other service, as is so commonly done.

A very small fitting which is seldom seen on these heaters, but which must make a difference to efficacy, is an air vent. If the steam were blown free through the heater it would not be needed, but instead of this the heater is worked under somewhat similar conditions to a steam radiator, and an air vent is absolutely necessary to the latter. It may be that the engineer is expected to blow through the heater each day, but even if this were done the air vent might still be put, and in many cases it would make a noticeable difference to efficacy.

The fixing of a horizontal heater is simple. It is usually most convenient to suspend it from the ceiling by two or three wrought-iron straps, and the connections consist of the steam supply, the condense, and the hot-water pipes. The condense can be carried to a trap, or the feed-water tank; or it can be returned direct to the boiler if the heater be high enough and if the steam supply has not been reduced.

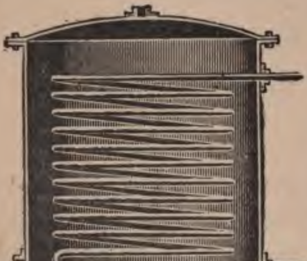

FIG. 113.

Fig. 113 is from a manufacturer's list, and it does not show all the requisite details. It, however, shows the manner in which the steam affords heat to the water. This would be fixed with the tank or case upright, and the tube of the coil horizontal, as illustrated. It could not be placed the other way, as every turn of the coil would then form a collecting place for condense water.

As to the efficacy of heaters of this class, this must depend on the pressure of steam and the temperature to which the water is to be raised. As this kind of heating is mostly used in institution work—which is the subject of severe competition—the water in the radiators is usually reckoned on being 200°, for only by this means can the cost be kept low. The hotter the radiator the smaller it can be, and as the total radiating surface is reduced, so the size of the hot-water mains can be lessened also.

There is no great objection to hot-water radiators being 200° (in times of frost, as compared with 170° which is usual with residence work), provided this temperature can be kept regular and not go up to boiling point. There is a great uncertainty about this with a hot-water boiler unless very carefully tended and a thermometer on the flow-pipe watched; but with a steam heater, provided the steam supply is constant, the temperature of the water can be fixed with the greatest nicety and then remain regular so long as the stopcock is untouched.

Supposing the temperature of the water is 200°, then with the air at 62° to 65° a square foot of radiator surface would lose 250 heat units per hour.* This with steam at 15 lbs., and return water at 150°, would give 30 feet of radiator surface to 1 foot of heater surface, transferring 7500 units per hour per average foot of surface. With an absolutely perfect heater these figures could be increased.

With the water at 170° a square foot of radiator surface loses about 185 units per hour only, and an average square foot of heater surface is therefore capable of dealing with just over 40 feet of radiation. This, however, would be an impracticable temperature to work upon, for 170° as the maximum heat obtainable in a radiator is not sufficient, unless the radiator surface was very liberal and could ordinarily afford heat enough with its water at 150° to 160°.

With steam at 15 lbs. pressure it is best to consider, for ordinary purposes, that one average foot of surface in a properly made heater will heat 32 to 35 feet of radiation. This is for ordinary good conditions. If the steam supply fluctuate, or the service to heater be long and small for its length, or any condition exist which may be considered as detrimental to results, the radiation figures must be reduced.

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* Varying of course with the design of radiator, its height, the grouping of its tubes, and whether it stands clear away from the wall, as it should do.

To calculate the efficacy of steam at higher temperatures, the table of temperatures for pressures in the Appendix can be referred to. The hotter the source of heat the less heater surface there need be for given results. Steam at 15 lbs. pressure (above atmospheric pressure) is 250°, while at 52 lbs. it is 300° or one-fifth greater. It follows that 1 foot of heater surface at the latter temperature will give one-fifth greater results than at the former. In practice this is not always quite obtained, and the best rule is to calculate a fifth as a sixth only.

CHAPTER X.

HIGH-PRESSURE STEAM HEATING.

HIGH-PRESSURE steam, for the purposes of this chapter, may be considered as steam which is at 30 lbs. pressure to the square inch or higher. It is not often that steam of this temperature is used for warming rooms; yet occasionally, especially for drying-rooms and trade purposes, it is preferred. As a rule it means using the steam direct from a power boiler without reducing pressure.

Of course, steam at high pressure is also steam at high temperature, as the table in the Appendix will show, and the heat of these pipes is such that there should be no risk of people who are ignorant of their temperature touching them. They will also make the air a little drier than pipes of less heat, and if dust be allowed to collect on them there is a greater possibility of its creating an odour or taint to the air.

All these things count for nothing when the pipes are used for trade purposes, and the dryness of the air is always an advantage in drying-rooms.

In carrying out these works the entire system would probably consist of pipes. Radiators may be used with steam up to about 40 lbs. if they have metal-to-metal joints, but it must be stated that the makers of these goods do not anticipate their having to bear a pressure any greater than this or quite as great.* The writer has some working satisfactorily with 60 lbs. steam, but this could not be guaranteed in the ordinary way. An exception may be made to this with the wrought tube radiator, which consists of a number of vertical tubes screwed into a base, and which may be used with steam up to, say, 70 lbs. Fig. 114 illustrates this radiator, which can be had with two or more rows of pipes if desired. The top casting is loose.

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* A hot-water apparatus in a high building, with say 80 feet vertical between the cold cistern and the lowest radiators, would cause the latter to have 34 lbs. pressure to the square inch within them.

When radiators are not used the piping can consist of mains and branches, the same as with low-pressure work, but a length of pipe is substituted for the radiator. Fig. 115 shows a one-pipe connection, while Fig. 116 shows two-pipe. These are simply single lengths of pipe, and if two or more lengths are required with a one-pipe connection they can be joined up at the ends, as Fig. 117. With two-pipe connections a coil, as Fig. 118, can be used, but the pipes must be kept quite horizontal.

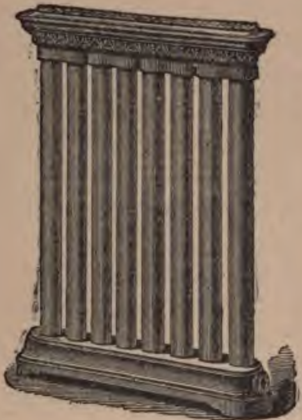

FIG. 114.

If the place to be heated be one large room, or a series of rooms in which the temperature need not be independently controlled, then the piping might be taken to the highest point first and from thence carried as a continuous run through the rooms, to and fro if necessary, and back to the boiler, falling all the way. It could be carried out, in this respect, like a high-pressure hot-water apparatus, only that the circulation rises to the highest point as quickly as possible and then falls all the way. There could be several such circuits if desired, and each of these could have a stop-valve for independent control.

The condense can be returned to the boiler if possible; that is, if the piping work be wholly above the boiler the condense water will come back in the same way as with the low-pressure gravity systems described in Chapter IV. If this be impossible, owing either to the radiation being too low, or to the steam in the radiator having been reduced by some means, then it is best to discharge the condense through a trap, from whence it can go to the feed tank, or be used for any other purpose.

The fittings for this work have to be of the best to withstand the pressure and high temperature. Valves and air vents must be specially ordered, that is, the manufacturer must be informed of the pressure. Traps must also be suited, and, not least important, the question of expansion and contraction of the pipes must be considered more carefully than ever.

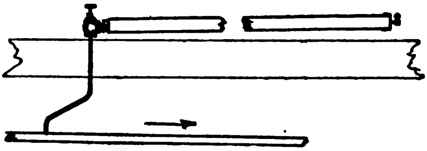

FIG. 115.

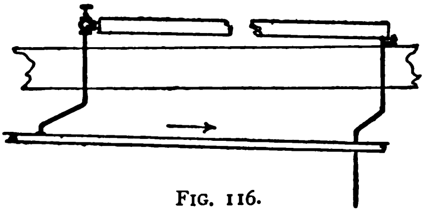

FIG. 116.

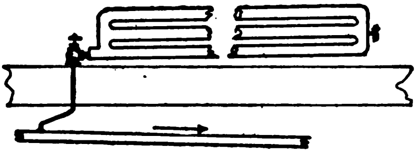

FIG. 117.

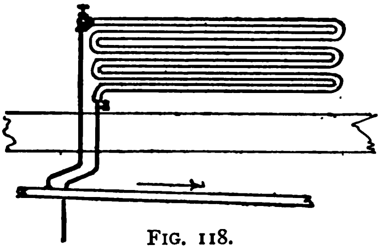

FIG. 118.

In regard to the area of heating surface required to afford certain temperatures, it is safe to calculate this by the proportions between the heat of the high-pressure and that of low-pressure steam. Low-pressure steam, as generally used, has a temperature of 220°, and this may be considered as the heat of the radiating surfaces. Steam at 90 lbs. pressure has a temperature of 331°,* and this may be said to be its radiating surface heat. The proportions are 1·0 and 1·5, the 90 lbs. steam being 50 per cent. hotter than the low-pressure and therefore capable of affording 50 per cent. more heat, or of doing a given amount of work with one-third less surface. Steam at 30 lbs. is 275°, or one-fourth hotter than low-pressure steam, therefore capable of doing a certain amount of work with one-fifth less surface.

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* See table in Appendix for temperatures of steam at various pressures.

The sizes of mains or supply pipes for high-pressure steam can be smaller than for low-pressure. It is best not to let pressure or force enter into this calculation, but to assume that whether high or low-pressure steam is used, it travels fast enough to keep the void filled which condensation causes. No doubt high pressure does assist, and would overcome the retardation of a small pipe better than a much lower pressure would do. In calculating on the volume of the steam alone, however, the reduction in the sizes of pipes is ample.

Steam at ordinary low-pressure, 2 lbs. to 3 lbs. on the gauge, occupies about 1400 times the space that an equal weight of water does,* while steam at 30 lbs. is 576 times greater only, and at 60 lbs. 355 times, and so on. Thus if a 2-inch pipe were needed for low-pressure steam (as given in the Tables in Chapter IV.), steam at 30 lbs. would require a full 1¼-inch pipe, and at 60 lbs. the pipe need be barely larger than 1 inch.

Occasionally high-pressure steam is used "expansively" as it is called. In this case the piping is arranged in as much of a continuous run as possible, with a fall all the way as usual. The steam is allowed to blow through this and escape at the end, which is left as an open pipe. This is not an economical plan, although the valve in the supply pipe can be regulated to let no more steam pass than absolutely necessary. There would, however, still have to be an issue of steam from the open end. Carried out in this manner no precautions need be taken to withstand high pressure, as will be understood. The pressure would be quite low.

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* See table in Appendix.

CHAPTER XI.

SUNDRY INFORMATION AND DATA RELATING TO STEAM HEATING.

Disappearing water-line in steam boilers—Effects of condense water on iron—Covering pipes to prevent loss of heat—Lime deposit from hard water—Extracts from the London Building Act.

Disappearing Water-line.—It sometimes happens that the water-level in a boiler will fluctuate to a large extent, or occasionally quite disappear, and as this is a more or less serious occurrence, some information gathered from different sources may be of service. There are two reasons for the water leaving a steam boiler. One is defective boiler construction, in which the heating surface is so sensitive and the provision for circulation so defective that steam and water combined are thrown from the heating surface into the mains. The other is a defective arrangement of the piping, preventing the water of condensation being returned promptly and freely to the boiler. This behaviour of water in a boiler also appears to have some relation to the presence of oily matters, since washing out a boiler with soda and recharging it with clean water sometimes corrects the fault.

An instance occurring to an American engineer is described as follows. The boiler in question had a 2-inch circulating pipe, connecting the upper section at water-line with the bottom of fire box section, so the trouble could not be attributed to poor internal circulation.

The piping was the one-pipe circuit system, a 2-inch main rising to the highest point above, and pitching down ¼-inch to 1 foot back to the bottom of the boiler. One-pipe branches were taken from this main to five radiators.

The trouble consisted in the lowering of the water in the boiler from 8 to 12 inches on starting steam. When first installed the system seemed to work perfectly, but in the course of two weeks the trouble developed, and after four weeks' use, the water would drop from 10 to 12 inches on getting steam with system cold. After the system was filled and hot, the water would rise to original height.

Experiments were made with the piping, air-valves, etc., but with no improvement. It was finally remembered that, on setting up boiler, a quantity of oil and chips were found in the drop tube, which had been cleaned out as well as could be done conveniently, and it was thought that the trouble might be caused by the oil, etc., which was not got out, although the water was very clear in the glass. About a pound of sal soda was put into the boiler and it was heated up for about thirty-six hours. At the end of this time the water was black, and foaming badly. The boiler was then given a good washing out and refilled. There was no more trouble, and the water-line remained as steady as could be wished.

The following is an account of a disappearing water-line as described by John Gormly, an American engineer.

Having occasion recently to locate a steam boiler of the pattern usually designated a "saddle boiler," with a fire 12 by 16 inches, and a maximum rated capacity of 150 square feet of radiation, tapped 2½ inches on the top for a steam pipe, I attached to it 120 square feet of steam radiation. The mains not being covered, would run the radiation up to 150 square feet. Of this amount 25 feet were on the second floor, 45 feet on the first floor, and 50 feet on the ground floor. The boiler was located in the basement in such manner that in no case was there more than 12 feet of a horizontal run. The pipes were graded with a fall of one inch in ten feet. I connected all the radiators on the single-pipe system, the condensation being returned through the steam supply pipe of each radiator. I placed on each radiator an automatic air valve with a hard rubber pencil, the expansion of which closed the valve when heated. All radiators containing above 25 square feet of surface had 1¼-inch connections; all below that size had 1-inch pipe. So far this was the customary practice, but I could not refrain from experimenting on so small a plant, as the cost would be little and a demonstration would be as effective as one on a more expensive apparatus. I therefore graded the pipes so that the rise was from the boiler to the radiators, placing no drip or relief pipes on the job. The water of condensation necessarily ran in a contrary direction to that in which the steam travelled. There was no other connection between the bottom and the top of the boiler than a 1¼-inch pipe, to the side of which the water column and gauge glass were attached. The boiler was connected to an excellent flue. On firing up the water remained in the water glass until one-half pound was registered on the gauge. At that pressure the water disappeared down the water glass with a steady motion and so swiftly that in ten seconds it was out of sight. I then opened the fire door. The water returned as swiftly as it had gone. I repeated this experiment several times, the disappearance and return of the water occurring each time. Had I been experimenting to discover a pump to throw water to the upper floors with one half-pound pressure this apparatus would have been a success. I then tried to determine the effect of placing ¾-inch drip pipes at the foot of all the vertical risers, of which there were three. These drip pipes were carried separately to the base of the boiler and there attached to it. On again firing I was somewhat surprised to discover that I had made no change in the working of the apparatus, unless it was to accelerate the disappearance of the water. I then assumed that the automatic air valves could be blamed for part of the effect, the loose hard rubber stems of the valves slipping over the passage from the valves into the radiators and acting as a check to the admission of air when a partial vacuum was in the radiators. I then replaced the automatic valves with others having no rubber pencil, but operating with a metallic bar, which by expansion and contraction, opened and closed the valves. These were positive in action and could not be closed unless the radiator was filled with steam. On firing up again I had the same result as at first, which was a surprise.

I now looked to the boiler for the cause of this peculiar action. I noticed that when the water-line of the glass was out of sight there was always a steady stream of water, very small, but yet very perceptible, running spirally down the glass on the inside. I decided to tap the two main steam branches close to the boiler and directly above it, in such a manner that any water running along the bottom of the mains would be intercepted. It was also intended that this pipe should act as an equalising pipe. It was made large and the base of it tapped into the bottom of the boiler. When again fired up it was found that a steady water-line was maintained. The plant has now been running steadily for two months. It gives entire satisfaction.

I have concluded that in this instance the form of the boiler was the cause of the peculiar action of the water. The boiler had probably no more than an inch of water surrounding the fire box. There was no local circulation possible in the boiler as it came from the makers. I believe all boilers should have a good circulation of the water contained in them, and that a steam boiler should contain much more water within itself than a water boiler. I wish to call special attention to the fact that in this experiment all the radiators, even to the second floor, were filled to the line of the automatic valves with water. As the second floor radiator was about 30 feet above the boiler, and as there was but one-half pound of steam on the plant, it is difficult to state the cause of water being forced to that height.

As the automatic valves were open and could not be closed while they were cold, it was not a vacuum that held the water in the radiators; but what did hold the water there? Personally, I incline to the view that the pipes and radiators were filled with globules or bubbles of water and steam alternating with each other in much the same manner that water is pumped by the Pohle pump, except that in the Pohle system air is used instead of steam. I believe these globules or bubbles would be materially assisted in their formation by the oil left in all pipes by the fitters. On mentioning the peculiar action to a friend, he assured me that with the same make of boiler a vertical line of single pipe to three floors had acted in much the same manner with him, but in his case the lower radiator was hot and the radiator on the first and second floors remained cold and were partially filled with water. He remedied the trouble by tapping the boiler both at the water-line and at the base, then connecting the two taps with a 2-inch pipe. This settled the trouble. His water-line was a disappearing one before he made the connection on the boiler which I have described.

Effects of Condense Water on Iron.—The condense water from a steam heating plant is soft and has all the properties and effects of rain water. One noticeable effect is the way in which it attacks iron, the action being destructive in a marked degree. It is an oxidisation that occurs, and Fig. 119 will show the result as it occurred to a larger number of radiator nipples in one apparatus. The radiators had been in use about seven years when the renewal of nipples became necessary.

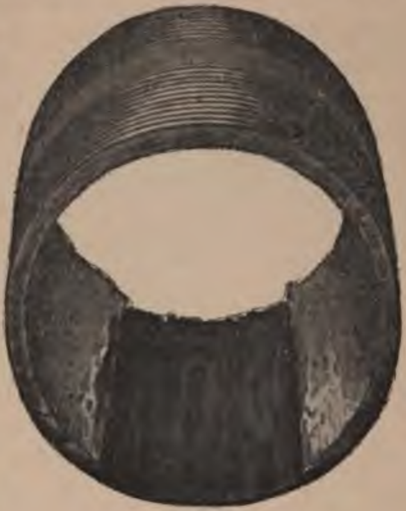

FIG. 119.

The cause of the fault was obvious enough, as it only existed just where the condense water trickled along, but another noticeable thing was that these nipples, which were of wrought iron, were attacked to a far greater extent than any cast-iron surfaces that the water passed over. The outcome of this was the testing of some malleable iron nipples, and these are now considered to be the best for the purpose.

The destructive action of soft water on iron, and some other metals, has been long known, and it has also been noted that hard water, having lime in solution, is without this injurious effect, or it is greatly lessened. It has also been known that the presence of lime in water opposed the oxidising process, and why this should be so was made the subject of an inquiry and experiment. The outcome was the discovery that rusting did not occur actively, or indeed at all, if carbonic acid was not present, and as lime has a considerable affinity for this gas the presence of lime in water caused the water to be apparently free from the gas. Both water and air contain carbonic acid, in the character of an impurity, and it would be very difficult of removal were it attempted. The action of the gas in assisting oxidisation, however, can be largely neutralised by the presence of lime.

FIG. 120.

Covering Pipes to Prevent Loss of Heat.—Correctly speaking, every inch of a steam-heating plant, except the radiating surfaces which are intended to afford warmth, should be covered to prevent loss of heat. Heat given off by a steam main or branch represents waste of fuel, the same as in a hot water apparatus, but it also has two disadvantages that the hot-water pipe has not. One is that loss of heat means condensation and loss of steam, the annihilation of some of the heating agent. The other is that the existence of this extra condense water is a fault in itself, for every effort is made to keep this as small in quantity as possible, and all the engineer's skill is required to prevent it giving trouble. The actual loss which may occur is very uncertain owing to the many different conditions, but in all cases an uncovered pipe means a loss, and a fault small or great, and the practice of covering these pipes should be universal. When the pipes are uncovered they have to be calculated as radiating surface, when deciding the sizes of boiler and mains, and a little calculation will show that about 23 superficial feet of surface of these mains will account for one pound of fuel per hour in the boiler; over a half-ton each winter season.

The materials for covering low-pressure steam pipes are as varied as those used for hot water, as a temperature of 220° to 230° is not destructive to the ordinary fabrics used. With high-pressure steam it is another matter, as Fig. 120 will show. This represents a piece of wood casing surrounding a pipe conveying steam at 100 lbs. pressure, but between the pipe and the wood was $\frac{1}{8}$ of an inch thickness of asbestos cardboard next the pipe, and $\frac{1}{2}$ an inch of hair felt next that. The felt was reduced to powder and the wood charred to the extent shown.

For ordinary low-pressure purposes hair-felt ranks first, but it is thought to have a bad exterior surface unless plastered over, or covered with canvas wound on and tied. The writer has introduced a felt covering as Fig. 121 * which overcomes the difficulty, as the exterior is hard straw-board, smooth and clean. It is easily put up and as easily taken down and replaced again if necessary. Other coverings consist of wood casing packed with hair or silicate cotton, also the many patented compositions that are to be had. Silicate cotton ranks with the best of coverings, and it is both cheap and clean to use. It, however, requires a casing of some kind, though it can now be purchased sewn to strips of canvas for winding on spirally. The compositions are made up of various inexpensive ingredients, and it would not be difficult to make one up as required. Materials such as cork in a coarse dust, chopped cocoanut fibre, hair, coke-breeze and

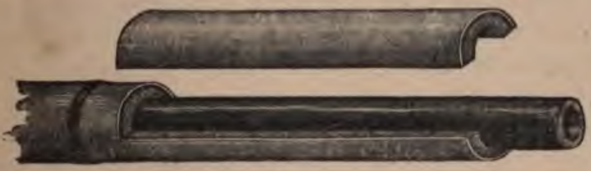

FIG. 121.

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* Frederick Dye, 30 Lewin Road, Streatham, London, S.W.

brickdust, mixed up with fire clay and a little plaster, would serve excellently. The mixture would be applied wet, like mortar, and on drying would have all the essentials of a poor heat conductor.

Nearly all compositions of the kind require to be applied to the pipes when the latter are hot. A thin layer is first applied and this is rubbed on (with a piece of material or the hand) and allowed to dry. It then forms a key for what follows, and which is applied with a trowel. It is better to put the remainder on in ½-inch layers to the required thickness, rather than put one thick coat on at once. Each coat should be allowed to dry before applying another, but drying occurs very rapidly on the hot pipe.

A poor conductor of heat relies for its efficacy on having innumerable air spaces in it, when dry and in use. Air is a poor conductor of heat, one of the most successful, but it must be confined. Air is slow to receive heat and slow to part with it, but if the air can move it will leave the hot surface the instant it receives warmth, and be replaced with cold air, which just as quickly gets warm and departs also. A steam pipe surrounded by free air is quickly robbed of its heat, but when surrounded by confined air it has its heat successfully conserved. Solid materials are mostly good conductors, porous materials which have their grains or parts ill-fitting, with air spaces between, are poor conductors.

The following are brief tables showing, firstly, relative conducting qualities; secondly, relative poor-conducting properties.

TABLE OF HEAT CONDUCTIVITY.

(*Box.*)

Eider down	0·314
Felt	0·323
Sawdust	0·523
Coke pulverised	1·29
Stone	13·68
Iron	233·00
Copper	525·00

TABLE OF RESISTANCE TO HEAT CONDUCTIVITY.

(*Thurston.*)

Felt	1·000
Silicate cotton	0·832
Sawdust	0·523
Pinewood	0·553
Gas house carbon	0·570
Asbestos	0·363

Lime Deposit from Hard Water.—When the water with which a boiler is fed is hard, with lime in solution, a precipitation of solid particles of lime occurs when the water boils. With one, or a few charges of water, the quantity of lime deposited is so small as to be scarcely perceptible, but if the water is changed two or three times a day for say six months the collection of lime will be getting serious.

With boilers heating a gravity return system, as described in Chapter IV., the same water is heated over and over again so that the lime deposit may be said not to exist, as the amount would be so exceedingly small even with the hardest water. When a charge of hard water is heated and first deposits its lime it has no more lime to deposit afterwards. It is only when new water is introduced that a further deposit is added to the first. As a gravity return system may not lose a boilerful of water in six months, the deposit question needs no thought whatever. If on the other hand the condense water is discharged from traps and quite new water is being fed into the boiler hourly or oftener, then the deposit question needs as much thought as any other that the erection of the apparatus involves.

Our supply of hard water (practically all of it) may be considered to be limited to that which proceeds either through or from lime or chalk strata, and as this water is usually of a crystal-like clearness, it is difficult for the uninformed to make it accountable for the hard stony deposit (limestone, in fact) that incrusts the inner surfaces of the boilers.

To explain the cause first, the generally accepted theory is as follows:—

Water which descends to the earth in the form of rain comes into contact with, and readily takes up, carbonic acid, either from the air in which this gas is present to a considerable extent in the vicinity of populated places, or from decaying vegetable matter in the open country. This water, charged with carbonic acid gas, percolates through the earth, and immediately it comes in contact with chalk (carbonate of lime, calcic carbonate) the acid enters into combination, producing bicarbonate of lime (calcic bicarbonate), which is highly soluble in water—in fact, may be considered as a fluid itself. It is very necessary to notice this peculiar difference between carbonate and bi-carbonate of lime, as it is wholly accountable for the trouble now under discussion. The former, of which we speak as chalk, consists of lime having a certain quantity of carbonic acid gas held in combination with it, and this substance is but sparingly soluble in water. Bi-carbonate of lime consists of precisely the same materials, but the quantity of acid gas is exactly double, and this renders it highly soluble in water.

It will now be understood that the supply of this hard water is confined to districts where chalk abounds in the soil, and the degree of hardness naturally varies with the nature of the ground. In the South of England, including London and many counties south of London, nearly all the water is more or less hard, but in the north of England the water is of quite a different character, and hard water is, to a great extent, unknown.

When a new boiler is first charged with hard water and sufficient heat is applied, the result is to drive off the proportion of acid gas which goes to make the carbonate into bi-carbonate of lime. The latter is then transformed into the former again, which, being insoluble, is precipitated. This precipitation does not wholly take place immediately heat is applied, but proceeds slowly until boiling takes place and steam is formed, when the chief precipitation is effected. It is almost needless to add that the greatest quantity of deposit is found at that part of the boiler where the greatest heat is felt.

The amount of lime deposited when using a boiler but once is a very minute quantity, but when the same water does not stay in the boiler and fresh water is being continually brought in, we can then understand why the deposit seems to accumulate so rapidily. The heated and (wholly or partially) softened water passes away first as steam and then as condense water, which escapes from the trap.

If the condense water discharged by a trap is used as feed water and very little new water is required, then the deposit is proportionally small, almost as little as occurs with a gravity return, and it needs no thought.

The ill effects of this furring consists firstly (and most especially) in its causing a boiler to become fractured before an eighth of its natural life of service has expired; secondly, a comparatively thin coating of deposit will materially lessen the rapidity with which the water heats, as carbonate of lime is such a poor conductor of heat.

It might have been mentioned earlier that the ill effects brought about by the deposit are largely due to the form of boiler used. What may be considered as an ordinary detail in upright boilers, and in many horizontal kinds, is that the water-way around the fire box terminates at bottom level with the fire-bars. A reference to any boiler makers' catalogue shows this, about the only common exception being the Lancashire types, a cross-section of which shows the water-way carried right under the fire-bars and ash-pit. This boiler is a horizontal water-jacketed cylinder, in fact, as every engineer knows.

Now when the water-way goes no further down than level with the fire-bars it follows that any solid particles (the precipitated lime) falling down through, the water must collect chiefly at this low point. This is so, and the fault of it is that the accumulation occurs where the greatest heat is felt. The effect of the heat is firstly to make the lime become a hard incrusted mass, and secondly to destroy the boiler plate when this incrustation prevents the water having contact with the boiler plate.

Both these ill effects can be obviated by arranging for the deposit to collect somewhere else, where there is little or no heat, and this is best done by extending the water-way down below the fire-bars. If the precipitated matter settles below the level of the fire, where there is so much less heat, it would not matter, in a sense, if the lime did keep the water from the iron, because the iron receives no destructive degree of heat there; but, better than this, the intense fire heat being absent, the deposit does not harden and incrust. It only collects as a soft mud which can be scraped out periodically through a cleaning hole provided.

As a rule this extended water-way, below the level of the fire-bars, is carried right under the ash-pit, so that the bottom of the boiler, next the base it stands on, is a water-way.

The object of this is to facilitate cleaning, as the collected deposit can then be all got out of one hole. If the water-way ended around the margin of the ash-pit it would save the boiler equally well, but it would need at least three holes to get the deposit out of this marginal space (round the circumference of the boiler).

It can be repeated that the deposit question needs no thought with boilers having all their condense water coming back to them, either by gravity or by means of a feed tank and pump. It is only boilers which have new water fed into them with some frequency, and some quantity, that the deposit must be provided for, but only then if the water is hard, having lime in solution.

The London Building Act, as it concerns the Heating Engineer.—When the Metropolitan Building Acts were in force, a rule stated that steam and hot water pipes were to be kept a certain distance from wood and other inflammable material unless the steam or hot water was at low-pressure. No definition of low-pressure was given and it was left for those in authority to interpret the meaning. As a rule a liberal interpretation was given, and no trouble ensued. Now the later Act of 1894 defines the term low-pressure to mean an apparatus of pipes conveying steam or hot water, and having a "free blow-off." It puts the steam engineer in a worse position than ever, as will be seen in the following extracts :—

EXTRACTS FROM SECTIONS OF THE LONDON BUILDING ACT, 1894, RELATING TO WORK EXECUTED BY HEATING ENGINEERS.

It may be as well to state first that the old Metropolitan Building Act, and the Amendment Act, are both extinct. This new 1894 Act is complete, and over-rules previous Acts of the kind.

"A pipe for conveying heated air or steam shall not be fixed nearer than six inches to any combustible materials (*see next page*).

"A pipe for conveying hot water shall not be placed nearer than three inches to any combustible materials (*see next page*).

"Provided that the restrictions imposed by this section with respect to the distance at which pipes for conveying hot water or steam may be placed from any combustible materials shall not apply in the case of pipes for conveying hot water or steam at low pressure, "For the purposes of this section hot water or steam shall be deemed to be at low pressure when provided with a free blow-off. [*Note.—This qualifying clause gives liberty to run ordinary low pressure hot water pipes close against woodwork, as is commonly done; but with a low-pressure gravity steam apparatus working at* 5 *lbs. to* 10 *lbs. pressure, returning its own water to the boiler, and being therefore closed and having no free blow-off, a six-inch limit must be observed. This is not reasonable, as a low-pressure hot water apparatus extending up say fifty feet, can have its water raised to a higher temperature than* 10 *lbs. steam. Again, an exhaust steam apparatus with a free blow-off may oftentimes be served with steam at a much higher temperature than that in a low pressure closed gravity circulation. It will be seen that small bore hot water pipes (high-pressure or with valve) must be kept three inches from woodwork, which is three inches less than a steam pipe, though it is known that high pressure pipes attain high temperatures, always far higher than low pressure steam. It is a very awkward clause for the steam heating engineer, as no modern steam heating apparatus has a free blow-off.*—F. D.]

"A chimney breast or flue shall not be cut into except for the purpose of repair or during some one or more of the following things:—

(*a*) Letting in or removing or altering flue pipes or funnels for the conveyance of smoke, hot air, or steam, or letting in, removing, or altering smoke jacks.

(*b*) Forming openings for soot doors, such openings to be fitted with close iron door and frame.

(*c*) Making openings for the insertion of ventilating valves subject to the restriction that an opening shall not be made nearer than twelve inches to any timber or combustible substance.

"Timber or woodwork shall not be placed:—

(*a*) In any wall or chimney breast nearer than twelve inches to the inside of any flue or chimney opening.

(*b*) Under any chimney opening within ten inches from the upper surface of the hearth of such chimney opening.

(*c*) Within two inches from the face of the brickwork or stonework about any chimney or flue where the substance of such brickwork or stonework is less than eight and a half inches thick, unless the face of such brickwork or stonework is rendered.

"Wooden plugs shall not be driven nearer than six inches to the inside of any flue or chimney opening, nor any iron holdfast or other iron fastening nearer than two inches thereto.

"The floor under every oven, copper, steam-boiler or stove, which is not heated by gas, and the floor around the same shall for a space of eighteen inches be formed of materials of an incombustible and non-conducting nature not less than six inches thick.

"A pipe for conveying smoke or other products of combustion, heated air, steam, or hot water, shall not be fixed against any building on the face adjoining to any street or public way.

"A pipe for conveying smoke or other products of combustion shall not be fixed nearer than nine inches to any combustible materials. [*It is as well to exceed this distance when carrying sheet iron pipe beneath ceilings or near light woodwork, for should the pipe have its soot catch alight it may get red hot.*—F. D.]

"The floor over any room or enclosed space in which a furnace is fixed, or any floor within eighteen inches from the crown of an oven shall be constructed of fire-resisting materials.

"The jambs of every fire-place opening shall be at least eight and a half inches wide on each side.

"The breast of every chimney and the brickwork surrounding a chimney shall be at least four inches in thickness.

"A party wall at the back of every fire-place opening from the hearth up to a height of twelve inches above the mantel shall be at least eight and a half inches thick. [*This is insufficient if a skirting board, or dresser, or other woodwork is on the other side. The heat from a range boiler flue will char it. One inch of silicate cotton should be inserted.*—F. D.]

"There shall be laid level with the floor of every storey before the opening of every chimney a slab of stone, slate, or other incombustible substance, at the least six inches longer on each side than the width of such opening, and at the least eighteen inches wide in front of the breast thereof.

"On every floor except the lowest floor such slab shall be laid wholly upon stone or iron bearers or upon brick trimmers or other incombustible materials, but on the lowest floor it may be bedded on concrete covering the site or on solid materials placed on such concrete.

"The hearth . . . shall be solid for a thickness of six inches at least beneath the upper surface of such hearth."

CHAPTER XII.

COOKING BY STEAM.

A DIFFICULTY that every novice encounters when fitting up steam cooking plant is in deciding the size of boiler and the size of pipes. It is to be regretted that steam cooking practice is so limited that to reduce it to figures and calculations for boilers and steam services has probably never been thought of, and the writer can do little better than say that this knowledge comes by experience. Some attempt will be made, later in this chapter, to give approximate work values of different boilers, also the sizes of pipes needed, and from this a fitter can be guided to a useful extent. One desirable piece of information can be given now, which is that an apparatus has never yet been spoiled, nor prejudiced in any way, by having the boiler and pipes too large. If in doubt, be liberal in the sizes of both of these.

It may not often fall to the engineer who is a specialist in heating to have steam cooking apparatus on a very small scale to erect; yet this chapter would not be complete if the steam work of private residence kitchens were not described.

In the kitchens of good houses, establishments of some size, a small steam cooking plant is often put up. There are many things, fish, vegetables, hams, etc., that are cooked in a superior manner by steam, and the plant is put in on this account, and also to supplement the other cooking apparatus. Where convenient or desirable the kitchen range boiler is put to this service, and if the fire is of good size a very useful amount of steam can be got. If a steam boiler is put at the back of the range fire there is, of course, no accommodation for the customary hot water boiler, but in a large house this can often be arranged, as the demand for hot water is such that an independent boiler is required. It is seldom that a boiler behind the kitchen range will furnish an adequate supply of hot water for a really large house, and as an independent boiler has to be used for this, it can be easily arranged to put a steam boiler behind the range fire.

It is of very little use putting a steam boiler behind a range fire less than 10 inches wide, for a fire of a smaller size has comparatively no heat for constant steam making, remembering that the whole of the heat is not devoted to the boiler, nor much more than half of it. It is not worth while putting a boiler and all the fittings and connections for the trifling amount of work such a small fire and boiler could do.

It is best, in fact necessary, in all cases, not to attempt to supply the hot-water circulating apparatus from the same fire. It has been the practice to put *twin* boilers behind the fire, one of these heating the hot water circulation, the other geneing steam for cooking. Unless the fire was extravagantly wide for the size of range, this always meant two narrow, mean little boilers, neither capable of doing more than about half the work a fair sized house requires of them, and the result was a failure. Further, it could not be well arranged to put a separate flue and draught-damper to each ; consequently the fire acted on both equally. This meant heating both when only one was required, urging or checking both when only one needed it. It is a most unfortunate arrangement in point of efficacy and convenient working.

It should always be arranged to devote the fire wholly to the one steam boiler, or do without it ; unless by chance the range is a very large one for some reason and the fire, say, 16 inches wide. It would not be desirable to put twin boilers to a less size fire than this unless the work required of them should be very small. It becomes easily possible to use a steam boiler when two ranges exist, or, as more often happens, the hot water circulation is from an independent heater. Or there are instances where the users of the range require but one oven, and then one boiler is put behind the fire and the other at the unoccupied side.

The form that steam range boilers take is the "boot" shape, as Fig. 122, but it is much better to widen out the back, as Fig. 123, or adopt some other means of increasing the area of the water-line, also increasing the capacity of the steam chamber above the water-line. It has been proved beyond doubt, by the writer and others, that although the heating surface may not be increased, the yield of steam is much superior from a boiler like Fig. 123 than from Fig. 122. Incidentally, it may be mentioned that many designs of steam boilers for heating purposes appear to be deficient in water line area and in steam room above the line; not that the boilers may be inefficient heaters, but that their efficiency would undoubtedly be improved by attention to this detail. Experiments with these comparatively small range boilers show that best results are obtained when the steam chamber above water-line has a cubic capacity of one-third of the whole interior of the boiler, or, in other words, one-third the capacity of the space occupied by the water. This is assuming other conditions, generally, to be correct.

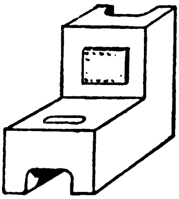

FIG. 122.

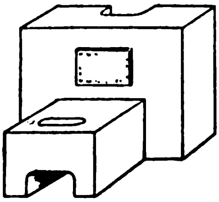

FIG. 123.

When it is possible the whole of the fittings are put on the boiler as in Fig. 124, this being a sectional elevation of the back part—the "leg" of the boiler. This is done when the leg of the boiler comes forward and is visible at the back of the range; but most ranges are constructed so that the leg has to be recessed behind the back coving plates, and is therefore out of sight. In this case a "hydraulic box," or feed cistern, is used, as in Fig. 125. The fittings are put on this, as of course they must come in sight somewhere. (See Fig. 91, page 156.)

Of the fittings, the water-inlet valve may be considered the most important. This is a pillar valve, with balanced arm having a weight at one end and a stone float suspended at the other. The float is a piece of sandstone about 8 × 6 × 1½ inches thick. This answers excellently. It will be seen that a pipe is attached to the pillar inside the boiler so that the incoming water may be delivered near the bottom and not at the top. The valve is fed from the house supply, or the main, but in the former case it is necessary to see that the house cistern is sufficiently high above to afford the necessary pressure.

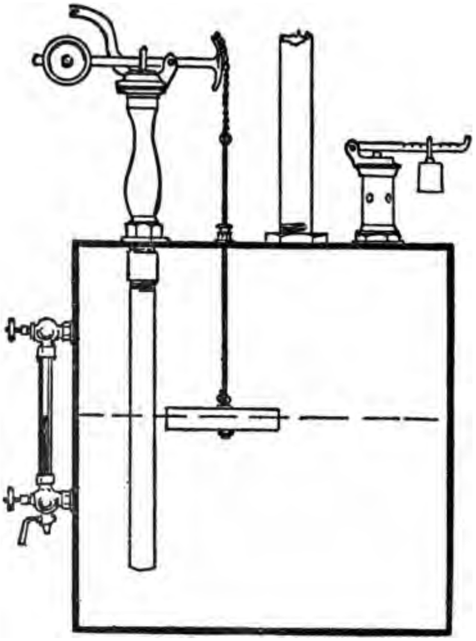

FIG. 124.

These boilers are worked at from 4 to 10 lbs. pressure, and if the water pressure does not exceed the steam pressure, the valve, when it opens, becomes a steam outlet instead of a water inlet. With steam at 10 lbs. pressure, for instance, the cistern would require to be at least 25 feet above the boiler, as the pressure of water in pipes is but 1 lb. for each 2 feet 4 inches vertical height. If the cistern were only 20 feet above no water would enter the boiler when the valve opened and the steam was at 10 lbs. gauge pressure.

Attempts are made to feed steam boilers with an ordinary open supply cistern and ball valve, trusting to a deep dip or "syphon" in the supply pipe to resist the back pressure of the steam. It is, however, a very poor arrangement, as the pressure must be kept down to about 1 lb., and the steam is then very wet for cooking.

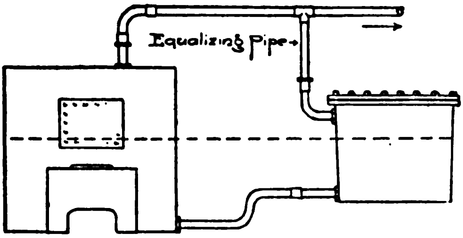

FIG. 125.

Where there is but one range and one boiler to it, attempts are made to use this as a steam boiler and heat the needed supply of hot water by steam from it. This is usually a failure unless the fire be large and the boiler proportionately powerful and effective. If it could be arranged that the boiler furnished steam for cooking at certain hours and heated water at other times, then it would seem a good arrangement, for there is the

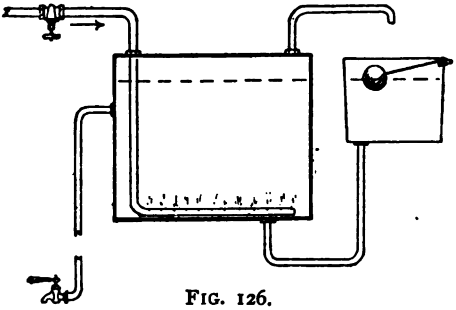

FIG. 126.

disadvantage, in many cases, that a steam boiler is boiling away for no purpose when the cooking is done. As a rule the servants draw water from it for kitchen purposes when not cooking, but it would be better if its heat were turned into a tank.

If the noise is not objected to the most effective and economical plan of heating water is by free steam, with a tank and piping fitted up as in Fig. 126. There should be a check-valve in the supply pipe, for should steam cease while the stop-valve is open some of the tank water will pass over by syphonage.

If free steam is not used then recourse is had to a coil in the tank. This coil can have its condensation pipe, its exhaust, taken back to the boiler, so as to form a complete circuit and waste no water, or it can be discharged by a steam trap, or pass into a closed tank. It is of little use attempting to trap the exhaust with a deep dip unless the steam carries but a light pressure. With 7 lbs. steam the dip would require to be about 18 feet to be successful.

In making up this coil it is very necessary that it be placed tight on the bottom of the tank, otherwise the water at the bottom will not become hot. In one instance a plumber had the correct quantities of piping given him for a coil which would boil the contents of a tank for tea and coffee-making. He fitted it up himself very well, but he put the coil quite six inches off the bottom of the tank. The result was that the water below the coil could rarely be got up to 100° Fahr., and it was easy to see what a prejudicial effect this had in getting the water above to boiling point. The improvement was extremely marked when the coil was put on the bottom—all the difference between success and failure.

Heating water by steam is more fully treated in Chapter IX.

About the smallest steam cooking apparatus that is ever fitted up is illustrated in Fig. 127. This shows, in sectional elevation, the side boiler of a single-oven cooking range with connection for furnishing steam to a cooking-pot, or "kettle" as the vessel is called. To effect this the boiler, in the first place, must be an effective heating one. One with a neck at the top as illustrated is usually the most effective kind. From the small steam space above the water line a ½-in. or ¾-in. pipe is taken to the kettle which is placed on a low shelf or on a table near by.

There is no condense pipe from the kettle, as a rule, for the amount of steam condensed is not large and the resulting water is emptied out when cooking is over.

The junction of the kettle and steam service is by the stopcock shown. This has a coned male outlet which fits a coned female piece attached to the kettle. The kettle is merely pushed tight on to the cock when the food stuffs are in it, and steam turned on. When the contents are cooked, the kettle is just drawn away and emptied in the usual manner.

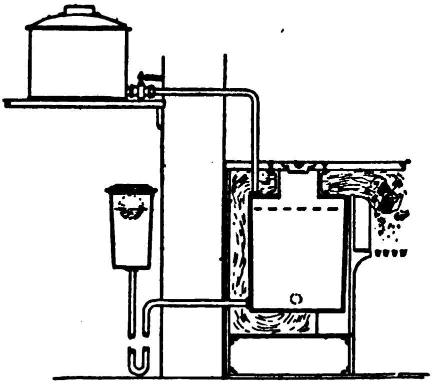

FIG. 127.

Two essential details are, a proper lid for the boiler, and a sufficiently deep dip in the cold supply pipe. Ordinary loose boiler lids are not steam-tight, nor heavy enough to make a pressure of 1 lb. to the square inch in the boiler. A brass lid is best, heavy enough for 1 lb. pressure, and this, with the rim into which it fits must be turned true to ensure a steam-tight fit without jointing material or fastenings of any kind. To calculate the weight of lid measure its area on the underside, and if it is 10 inches it should weigh 10 lbs. A little less will do, as ½-lb. pressure is practically sufficient for this purpose. The higher the pressure the drier the steam.

The cold supply is fitted up in the same manner as the ordinary self-filling apparatus put to these boilers at other times. The only difference, if it can be called such, is in the depth of dip. Ordinarily a 6-inch dip is ample, but this will not do when steam is made. The depth of dip will depend on the weight of the lid. If 1 lb. pressure is decided on the dip must exceed 2 feet 4 inches, making it preferably 3 feet deep. If the dip is insufficient, then the steam pressure will force the water from the boiler back into the cistern, where it will overflow and cause trouble generally. It will leave the boiler temporarily empty, or nearly empty, which results in injury by the fire beating on the empty part. It is very important that the dip be deep enough, as will be seen, for steam may be made at unexpected times, when no cooking is in progress.

The lid acts as a safety valve, lifting and releasing steam when the pressure exceeds one pound, provided, of course, that the dip is deep enough to prevent the pressure relieving itself by that route.

When steam is not required the tap in front can be applied to, and water drawn in the usual way. All the customary purposes of an ordinary hot-water boiler are served at such times.

The boiler of a 4-feet range will serve one kettle, and two kettles can be served from a 4-feet 6-inch range. This is supposing the boilers heat well, as they should do, and the fires are 10 inches and 11 inches respectively, or within half an inch of these sizes.

Whenever it is possible, the best plan is to have an independent boiler for steam cooking, and let the range boiler provide the hot water as usual. Hot water is needed every day and all the day long, just as long as the range fire is kept alight, and cooks are now conversant with the management of ranges so as to afford the needed supply of hot water at all hours.

The independent steam boiler, then, has its fire lighted as required. It may not be needed every day and seldom the whole of any day. In private residences, however large, the independent steam boiler has many idle hours and days, occasionally weeks. If it were a range boiler it would be making steam at all these times uselessly, worse than uselessly in fact, for the boiling is violent and the discharge of steam an annoyance. The independent boiler is of course much more effective than any range boiler, and this is an advantage.

In business houses, hotels, restaurants, and in institutions, the independent boiler is necessary, as a range boiler would not suffice. In such places the vegetables are cooked by steam, also hams, puddings, and many things. Then there are cutting tables and hot closets to be kept at a high temperature. These purposes may be fulfilled by the steam boiler for a much less number of hours than the range fire is alight each day, unless the hot water supply is heated by steam. In the latter case steam is needed at all hours.

Independent steam boilers, for cooking purposes, are always of a plain kind, either the common type of vertical shell with one or more cross tubes, as Fig. 128; or the ordinary dome-top vertical hot water boiler can be used, but it must, of course, have its inner crown put lower down to give the necessary steam chamber. Boiler makers are prepared to make the dome-top boiler (with which everyone is familiar) with the crown or top portion arranged for steam, at the same price as the boiler is in its usual form. The steam fittings would, of course, be extra.

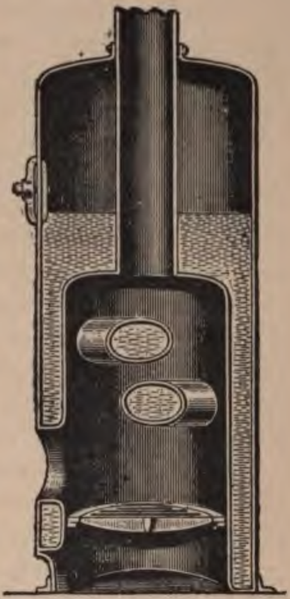

FIG. 128.

In cooking by steam the condense water is not returned to the boiler; consequently the water in the boiler must be replenished as fast as it passes away as steam. This can be arranged for by an automatic device, as described on pages 156 and 204, or should the water pressure be insufficient the boiler must be fed by hand, by injector or pumps.

As the condense water is wasted the supply of new water to the boiler is almost continuous, and if this water be hard the lime deposit quickly collects. On this account all steam cooking boilers, fed with hard water, must have their waterways carried down below the fire-bars. This is fully described on page 195, and it is more important than ever with the boilers now being referred to. In a business house, a large shop with indoor employés, there is a range boiler used for steam cooking, and this has to have the incrusted deposit cleaned out every four months. If the boiler is neglected for nine months it is destroyed. This is with London water, and it goes to show, as the writer has often experienced, that steam cooking boilers, any kind, should be cleaned out as often as hot water supply boilers are in the same district. This must not be neglected.

As to the capabilities of the various boilers a proper form of boot boiler in a kitchen range with 10-inch fire will work two small kettles, while with an 11-inch fire three small kettles can be supplied. A 12-inch fire can have two vegetable pots and a small pudding steamer, while a 14-inch fire (about the largest ordinarily put to kitchen ranges) can have three pots and a small cooking closet. With the latter fire the boiler might be worked with 6 lb. steam or a little higher, if the water supply pressure will allow.

It should not be attempted to heat the hot water supply by steam from a range boiler unless this can be done when the cooking is over, or between times.

For residence work, where the range boiler is used for hot water circulation, the independent boiler, as Fig. 128, is seldom needed, as a smaller size than this is made in will do. The dome-top recently spoken of is more suited, and sizes 3, 5 and 7 may be taken as suitable for large residence work. This latter term must not, however, be taken to mean the very largest establishments, for there are many which have, and use, more cooking apparatus than a private hotel. By large houses are meant those as in Prince's Gate, London, and entertaining freely. Such a house would require the No. 7 boiler for steam cooking, the hot water supply being heated separately.

Where steam is regularly used for cooking, some of the cooking vessels are often of the jacketed kind. These do not admit the steam directly to the foods which are being cooked but receive it in a shell or jacket around the cooking vessel proper. This is for boiling purposes only. Attention is called to the fact because jacketed vessels take longer to heat and require more steam, at a higher pressure, than vessels admitting the steam direct to their contents.

A No. 7 dome top boiler might be given two large cooking pans, a cooking closet and a hot closet; or the equivalent of this in smaller things.

For restaurant or hotel work the boiler as Fig. 128 is required. The smallest size of this is generally one horse-power. It is really very difficult to suggest the work this can do, as the conditions vary so greatly, but for the purpose of an example a 1 horse-power boiler might be given a ham closet, a pudding steamer, two or three large vegetable pans (one or two of them jacketed) a hot closet and cutting table. It would also heat all the water needed in the kitchen offices if applied to this when the cooking slackened off. This boiler would suit a large city restaurant, but would not be sufficient in some of the restaurants in the West End of London.

The amount of water that a boiler can heat is given on page 170.

AN INGENIOUS METHOD OF ERECTING FRENCH STEAM HEATING APPARATUS.

SINCE the major part of this book went to press, the writer has found described in a recent number of "Heating and Ventilation" a method adopted in the erection of steam-heating works, by French heating engineers, which must prove of interest to English readers, for it embraces some novel details.

Fig 129 is a reproduction of the published illustration, and the French engineers' description is as follows:—

"We have a great belief in steam heating, but had *not legal permission to place steam boilers in public or private edifices.* This was finally overcome by the use of boilers directly connected with the atmosphere by means of expansion tanks. Now there is one general method used by all contractors with but little difference in detail.

"The most conspicuous improvement consists in the expansion tank, which is now a leading characteristic of our French system.

"It may be mentioned that we do not allow the pressure in the boiler to rise above two metres of water column; the tank is consequently placed two metres above the ordinary water-line of the boiler. The water of condensation from the radiators flows back into this tank. It will be understood that the boiler must be placed in a pit deep enough for the two metres difference of water-line. Two pipes connect the boiler with the tank: one is connected with the bottom of the boiler, insuring a return of the condensed water, and the other is connected with the boiler just below the normal water-line, so that if the pressure in the boiler increases, the water-line falls and the steam escapes through the expansion pipe and tank. This constitutes a real safety-valve without any mechanical apparatus.

"An automatic valve for supplying the boiler with water is never used, the supply being furnished by an ordinary valve once or twice a day.

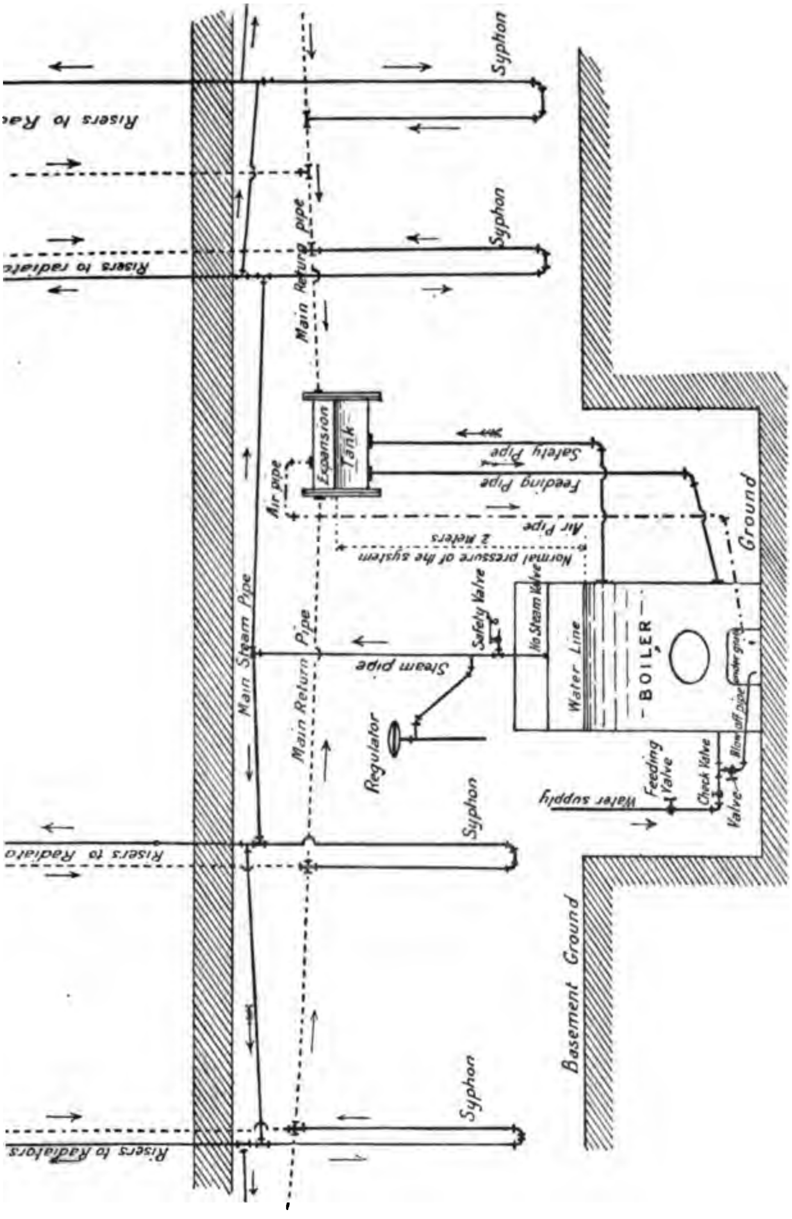
Risers to Ra
Risers to radiators
Risers to Radiators
Risers to Radiators
Syphon
Syphon
Syphon
Syphon
Main Return pipe
Main Return Pipe
Main Steam Pipe
Expansion Tank
Air pipe
Safety Pipe
Feeding Pipe
Air Pipe
2 Meters
Normal pressure of the system
No Steam Valve
Water Line
BOILER
Safety Valve
Steam pipe
Regulator
Water supply
Feeding Valve
Check Valve
Valve
Blow off pipe under grate
Ground
Basement Ground

FIG. 129.

"The boiler is supplied with an ordinary safety-valve, manometer, gauge-cocks, water-gauge, etc.; there is, however, no steam-valve, because this boiler always works at atmospheric pressure.

"The main steam pipe descends slightly from the high point near the boiler, and is connected by a syphon, as shown, to the return pipe of each riser. The risers are commonly exposed, but in important rooms they are run in grooves in the walls, concealed by wooden covers.

"The water of condensation is brought back from the radiators to the mains through little copper pipes, the main pipes being of iron.

"We never use air-valves. The air escapes from the return pipe through the expansion tank, which is open to the atmosphere.

"A free discharge of the air being thus insured, there is never any noise in the pipes; this is a fixed condition of all contracts. An apparatus in which noise can be heard would never be accepted.

"The method of regulating the heat of a radiator is entirely different in France from that in America. In the first place, we never use two valves, even when the two-pipe system is adopted.

"Our radiators are provided with one of two systems of regulation; with the first, the valve is regulated by the heating engineer when he contracts for the heating system, so that the valve shall only permit the passage of the quantity of steam that the radiator is able to condense, according to its radiating surface. So when the valve is fully opened it is impossible for any of the steam to pass into the return piping, and the return valve is quite useless. The return pipe being in full connection with the atmosphere by the expansion tank, the return water never backs up into the radiators.

"The second system of regulation, just as with ordinary valves, is under the control of the owner, who may regulate the heat to any desired degree. Frequently the valve has an index fastened to the wheel moving on a graduated dial-plate, showing the extent of the opening."

APPENDIX.

TABLE I.—TEMPERATURES AND PROPERTIES OF STEAM.

Vacuum Gauge, in inches of mercury.	Gauge Pressure, in lbs. per square inch.	Absolute Pressure.		Temperature in degrs. Fahr. of the steam, and of the water from which it is evaporated.	Number of Units contained in the Water.	Number of Units required for Evaporation, known as Latent Heat.	Total Number of Units contained in the Steam.	Volume. An Equal Weight of Water being 1.	Weight of one Cubic Foot in Decimals of a Pound.
		In lbs. per square inch.	In inches of Mercury.						
27·9	..	1	2·0	102·0	102·1	1042·9	1145·0	20620·0	·0030
25·9	..	2	4·0	126·2	126·4	1026·0	1152·4	10720·0	·0058
23·8	..	3	6·1	141·6	141·8	1015·2	1157·1	7326·0	·0085
21·8	..	4	8·1	153·0	153·4	1007·2	1160·6	5600·0	·0112
19·7	..	5	10·2	162·3	162·7	1000·7	1163·4	4535·0	·0137
17·8	..	6	12·2	170·1	170·5	995·2	1165·8	3814·0	·0163
15·7	..	7	14·2	176·9	177·4	990·4	1167·9	3300·0	·0189
23·6	..	8	16·3	182·9	183·5	986·2	1169·7	2910·0	·0214
11·6	..	9	18·3	188·3	188·9	982·4	1171·3	2607·0	·0239
9·6	..	10	20·3	193·2	193·9	978·9	1172·8	2360·0	·0264
7·5	..	11	22·4	197·7	198·5	975·7	1174·2	2157·0	·0289
5·5	..	12	24·4	201·9	202·7	972·8	1175·5	1988·0	·0313
3·5	..	13	26·4	205·9	206·7	970·0	1176·7	1846·0	·0337
0·0	..	14	28·5	209·5	210·4	967·4	1177·8	1722·0	·0362
..	0·0	14·7	29·9	212·0	212·9	965·7	1178·6	1644·0	·0379
..	0·3	15	30·5	213·0	213·9	964·9	1178·9	1612·0	·0387
..	1·3	16	32·5	216·3	217·2	962·6	1179·9	1514·0	·0413

TABLE I.—*continued.*

Vacuum Gauge in inches of Mercury.	Gauge Pressure in lbs. per square inch.	Absolute Pressure.		Temperature in degrs. Fahr. of the steam, and of the water from which it is evaporated.	Number of Units contained in the Water.	Number of Units required for Evaporation, known as Latent Heat.	Total Number of Units contained in the Steam.	Volume. An equal Weight of Water being 1.	Weight of one Cubic Foot in Decimals of a Pound.
		In lbs. per square inch.	In inches of Mercury.						
..	2·3	17	34·6	219·4	220·4	960·4	1180·8	1427·0	·0437
..	3·3	18	36·6	222·3	223·4	958·3	1181·7	1350·6	·0462
..	4·3	19	38·7	225·2	226·3	956·3	1182·6	1282·1	·0487
..	5·3	20	40·7	227·9	229·0	954·4	1183·4	1220·3	·6511
..	6·3	21	42·7	230·5	231·6	952·5	1184·2	1164·4	·0536
..	7·3	22	44·8	233·0	234·2	950·8	1185·0	1113·5	·0561
..	8·3	23	46·8	235·4	236·6	949·0	1185·7	1066·9	·0585
..	9·3	24	48·8	237·7	239·0	947·4	1186·4	1024·1	·0610
..	10·3	25	50·9	240·0	241·3	945·8	1187·1	984·8	·0634
..	11·3	26	52·9	242·1	243·5	944·2	1187·8	948·4	·0658
..	12·3	27	54·9	244·3	245·6	942·7	1188·4	914·6	·0683
..	13·3	28	57·0	246·3	247·7	941·3	1189·0	883·2	·0707
..	14·3	29	59·0	248·3	249·7	939·9	1189·6	854·0	·0731
..	15·3	30	61·1	250·2	251·7	938·9	1190·2	826·8	·0755
..	16·3	31	63·1	252·1	253·6	937·2	1190·8	801·2	·0779
..	17·3	32	65·1	253·9	255·5	935·9	1191·4	777·2	·0803
..	18·3	33	67·2	255·7	257·3	934·6	1192·0	754·7	·0827
..	19·3	34	69·2	257·4	259·1	933·3	1192·4	733·5	·0851
..	20·3	35	71·2	259·1	260·8	932·1	1193·0	713·4	·0875
..	25·3	40	81·4	267·1	268·9	926·4	1195·4	628·2	·0994
..	30·3	45	91·6	274·3	276·2	921·3	1195·6	561·8	·1111
..	40·3	55	111·9	286·8	289·1	912·3	1201·4	464·7	·1343
..	50·3	65	132·3	297·7	300·3	904·4	1204·7	397·7	·1570
..	60·3	75	152·7	307·4	310·1	897·5	1207·7	348·3	·1792
..	80·3	95	193·4	323·9	327·1	885·6	1212·7	280·6	·2224

TABLE II.—PRESSURE OF WATER IN SERVICE PIPES, ETC.

Feet Head.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.
1	0·43	27	11·69	53	22·95
2	0·86	28	12·12	54	23·39
3	1·30	29	12·55	55	23·82
4	1·73	30	12·99	56	24·26
5	2·16	31	13·42	57	24·69
6	2·59	32	13·86	58	25·12
7	3·03	33	14·29	59	25·55
8	3·46	34	14·72	60	25·99
9	3·89	35	15·16	61	26·42
10	4·33	36	15·59	62	26·85
11	4·76	37	16·02	63	27·29
12	5·20	38	16·45	64	27·72
13	5·63	39	16·89	65	28·15
14	6·06	40	17·32	66	28·58
15	6·49	41	17·75	67	29·02
16	6·93	42	18·19	68	29·45
17	7·36	43	18·62	69	29·88
18	7·79	44	19·05	70	30·32
19	8·22	45	19·49	71	30·75
20	8·66	46	19·92	72	31·18
21	9·09	47	20·35	73	31·62
22	9·53	48	20·79	74	32·05
23	9·96	49	21·22	75	32·48
24	10·39	50	21·65	76	32·92
25	10·82	51	22·09	77	33·35
26	11·26	52	22·52	78	33·78

TABLE II.—*continued.*

:et :ad.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.
79	34·21	87	37·68	94	40·72
80	34·65	88	38·12	95	41·15
81	35·08	89	38·53	96	41·58
82	35·52	90	39·93	97	42·01
83	35·95	91	39·42	98	42·45
84	36·39	92	39·85	99	42·88
85	36·82	93	40·28	100	43·31
86	37·25				

For rapid calculation it is a common practice to allow one pound pressure per square inch for every two feet height. This errs on the safe side. It is only vertical height that counts; a sloping pipe only causes a pressure to be exerted equal to the difference in height of the two extremities of the pipe.

TABLE III.—HYDRAULIC MEMORANDA.

A cubic foot of water weighs	62·32 lbs.
A „ „ „ contains . . .	6·232 gals.
A „ inch „ weighs	·03616 lb.
A cylindrical foot of water weighs . . .	48·96 lb.
A „ inch „ „	·0284 lb.
An imperial gallon contains	277·274 cub
An „ „ „	·16046 cub.
An „ „ weighs	10 lb.
A column of water 12 in. high, 1 in. sq. weighs .	·434 lb.
A column of water 12 in. high, 1 in. sq. contains	·0434 gal.
A ton of water contains	35·84 cub
A „ „	224 gals.
Cubic feet × 6¼ (nearly exact)	= gals.
Gallons × ·16	= cub. f
Expansion of water heated from 40° (its point of greatest condensation) to 212°	1 in 24
Expansion of water in freezing	1 in 12

TABLE IV.—RELATIVE AREAS OF IRON, WATER AND STEAM PIPES, FROM $\frac{1}{8}$ TO 9 INCHES INCLUSIVE.

(No Allowance for Friction.)

Sizes.	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	5	6	7	8	9
$\frac{1}{8}$	1	4	9	16	36	64	81	144	256	400	576	784	1024	1600	2304	3136	4096	5184
$\frac{1}{4}$	..	1	$2\frac{1}{4}$	4	9	16	25	36	64	100	144	196	256	400	576	784	1024	1296
$\frac{3}{8}$	..	..	1	$1\frac{1}{9}$	4	$7\frac{1}{9}$	$11\frac{1}{9}$	16	$28\frac{4}{9}$	$44\frac{4}{9}$	64	$87\frac{1}{9}$	$113\frac{7}{9}$	$155\frac{5}{9}$	256	$348\frac{4}{9}$	$455\frac{1}{9}$	$574\frac{8}{9}$
$\frac{1}{2}$	..	..	..	1	$2\frac{1}{4}$	4	$6\frac{1}{4}$	9	16	25	36	49	64	100	144	196	256	324
$\frac{3}{4}$	..	..	..	..	1	$1\frac{7}{9}$	$2\frac{7}{9}$	4	$7\frac{1}{9}$	$11\frac{1}{9}$	16	$21\frac{7}{9}$	$28\frac{1}{9}$	$44\frac{4}{9}$	64	$87\frac{1}{9}$	$113\frac{7}{9}$	144
1	..	..	..	..	..	1	$1\frac{9}{16}$	$2\frac{1}{4}$	4	$6\frac{1}{4}$	9	$12\frac{1}{4}$	16	25	36	49	64	81
$1\frac{1}{4}$	..	..	..	..	..	..	1	$1\frac{11}{25}$	$2\frac{14}{25}$	4	$5\frac{19}{25}$	$7\frac{21}{25}$	$10\frac{6}{25}$	16	$21\frac{11}{25}$	$31\frac{9}{25}$	$40\frac{24}{25}$	$51\frac{11}{25}$
$1\frac{1}{2}$	..	..	..	..	..	..	..	1	$1\frac{7}{9}$	$2\frac{7}{9}$	4	$5\frac{4}{9}$	$7\frac{1}{9}$	$11\frac{1}{9}$	16	$21\frac{7}{9}$	$28\frac{4}{9}$	36
2	..	..	..	..	..	..	..	..	1	$1\frac{9}{16}$	$2\frac{1}{4}$	$3\frac{1}{16}$	4	$6\frac{1}{4}$	9	$12\frac{1}{4}$	16	$20\frac{1}{4}$
$2\frac{1}{2}$	..	..	..	..	..	..	..	..	..	1	$1\frac{11}{25}$	$1\frac{24}{25}$	$2\frac{14}{25}$	4	$5\frac{19}{25}$	$7\frac{21}{25}$	$10\frac{6}{25}$	$12\frac{24}{25}$
3	..	..	..	..	..	..	..	..	..	..	1	$1\frac{13}{16}$	$1\frac{7}{9}$	$2\frac{7}{9}$	4	$5\frac{4}{9}$	$7\frac{1}{9}$	9
$3\frac{1}{2}$	..	..	..	..	..	..	..	..	..	..	..	1	$1\frac{15}{49}$	$2\frac{2}{49}$	$2\frac{46}{49}$	4	$5\frac{11}{49}$	$5\frac{30}{49}$
4	..	..	..	..	..	..	..	..	..	..	..	..	1	$1\frac{9}{16}$	$2\frac{1}{4}$	$3\frac{1}{16}$	4	$5\frac{1}{16}$
5	..	..	..	..	..	..	..	..	..	..	..	..	..	1	$1\frac{11}{25}$	$1\frac{24}{25}$	$2\frac{14}{25}$	$3\frac{6}{25}$
6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	$1\frac{13}{36}$	$1\frac{7}{9}$	$2\frac{1}{4}$
7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	$1\frac{15}{49}$	$1\frac{32}{49}$
8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	$1\frac{17}{64}$

This table shows at a glance the relative areas of different sized pipes. Thus, if it was required to be known how many $1\frac{1}{4}$-inch pipes have an aggregate area equal to one $3\frac{1}{2}$-inch pipe, it is only necessary to take the line from $1\frac{1}{4}$ inch in the left-hand column and follow it until beneath the larger size at the top of the table. The figure given, it will be seen, is nearly 8; in other words, a 3-inch pipe of a given length carries or holds nearly eight times as much as a $1\frac{1}{4}$-inch pipe. By reversing the process, the number of small pipes that equal a large pipe can be found, the large size being found in the top column and followed down until opposite the small size in the left-hand column.

TABLE V.

NUMBER OF SMALL PIPES REQUIRED TO MAKE AN AREA EQUAL TO ONE LARGER PIPE.—*R. C. Carpenter.*

(With Allowance for Friction.)

Size of Pipe.	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	4½ in.	5 in.	6 in.	7 in.	8 in.
½ inch	1·0	2·0	3·7	7·6	11·3	19·0	37·0	55·0	80·0	108·0	146·0	188·0	290·0	427·0	595·0
¾ "	..	1·0	1·8	3·7	5·5	9·2	16·7	25·5	39·0	53·0	70.0	90·0	143·0	210·0	295·0
1 "	..	..	1·0	2·0	3·1	5·1	9·3	14·7	27·0	30·0	39·0	53·0	80·0	117·0	165·0
1¼ "	..	..	..	1·0	1·5	2·6	4·5	7·3	10·6	14·7	19·5	25·0	39·0	57·0	80·0
1½ "	..	..	..	..	1·0	1·7	3·1	4·7	7·1	9·8	13·4	16·8	26·0	38·0	54·0
2 "	..	..	..	..	..	1·0	1·83	2·9	4·1	5·8	7·8	9·9	16·0	23·0	32·0
2½ "	..	..	..	..	..	..	1·0	1·7	2·5	3·5	4·7	5·9	9·3	13·7	19·0
3 "	..	..	..	..	..	..	..	1·0	1·5	2·4	2·7	3·5	5·4	7·7	11·0
3½ "	..	..	..	..	..	..	..	..	1·0	1·4	1·8	2·5	3·7	5·8	7·6
4 "	..	..	..	..	..	..	..	..	..	1·0	1·3	1·7	2·7	4·1	5·5
4½ "	..	..	..	..	..	..	..	..	..	..	1·0	1·25	2·0	3·3	4·1
5 "	..	..	..	..	..	..	..	..	..	..	..	1·0	1·6	2·5	3·2
6 "	..	..	..	..	..	..	..	..	..	..	..	..	1·0	1·5	2·0
7 "	..	..	..	..	..	..	..	..	..	..	..	..	..	1·0	1·4
8 "	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1·0

TABLE VI.

NATURAL HUMIDITY OF THE AIR AS NOTED AT GREENWICH, AND A MEANS OF TESTING FOR DRYNESS.

Month.	Mean Humidity for the 24 hours: Saturation = 100.	Month.	Mean Humidity for the 24 hours: Saturation = 100.
January . . .	89	August . . .	77
February . .	85	September . .	81
March . . .	82	October . .	87
April	79	November . .	89
May	76	December . .	89
June	74	The year . .	82
July	76		

A convenient means of judging the humidity of the air is by the dry and wet bulb hygrometer, as it is called. This consists of a pair of thermometers, one of which acts in the usual way, this being the dry bulb, whilst the other is covered with muslin and kept wet by a piece of material extending from the muslin to a small vessel of water. The water travels up this material by capillary attraction. The water in the muslin on the thermometer bulb is continually evaporating, and the degree of evaporation is according to the dryness of the air. As the water evaporates it has a cooling effect on the bulb, and the temperature recorded by the height of the mercury in the stem differs to that in the dry thermometer accordingly. The greater the difference the more dry the air must be, and in a case of extreme dryness a difference of 20 degrees might possibly be indicated. A healthful and proper degree of humidity is when the thermometers show a difference of 6 or 8 degrees, the wet bulb showing the lower temperature, of course. A difference of 10 degrees indicates dryness—too dry in fact, though not excessively so.

TABLE VII.

THE QUANTITY OF WATER THAT AIR IS CAPABLE OF ABSORBING TO BECOME SATURATED.

Deg. Fahr.	Grains per Cubic Foot.	Deg. Fahr.	Grains per Cubic Foot.	Deg. Fahr.	Grains per Cubic Foot.
10	1	60	5⅞	110	25½
15	1⅓	65	6⅞	115	30
20	1½	70	8	130	42½
25	1⅞	75	9¼	141	58
30	2⅛	80	10¾	157	85
32	2⅓	85	12½	170	112½
35	2½	90	14⅓	179	138
40	3	95	16⅝	188	166
45	3⅝	100	19⅛	195	194
50	4¼	105	22	212	265
55	5				

This table shows the necessity of affording moisture to air which is warmed to comparatively high temperatures, as with hot air works; it also shows what a high degree of efficacy hot air has in drying closets (provided it is extracted and replaced with new as fast as it becomes saturated).

TABLE VIII.

SIZES OF SAFETY VALVES FOR STEAM BOILERS.—*Box.*

Diameter of Valve.	Pressure of Steam in lbs. per Square Inch above the Atmosphere.		
	7	25	45
	Effective area of Boiler Surface in Square Feet.		
1 inch	7	17	27
1½ "	15	39	61
2 "	27	67	108
2½ "	42	105	170
3 "	61	151	243
	Nominal Horse-power of Boiler.		
1 inch	..	..	..
1½ "	..	..	3
2 "	..	3½	7
2½ "	2	7	13
3 "	3	11	20

The following gives the area of safety valves from a rule laid down for power boilers by the Board of Trade. It is a safe rule.

Boiler Pressure above the Atmosphere.	Area of Safety Valve in square inches for each square foot of Grate.	Boiler Pressure above the Atmosphere.	Area of Safety Valve in square inches for each square foot of Grate.
5	1·07	25	0·68
10	0·94	30	0·625
15	0·83	35	0·576
20	0·75	45	0·5

TABLE IX.

HEAT-CONDUCTING POWER OF MATERIALS (COMPARATIVE).

Copper	515·0	Gutta-percha	1·38
Iron	233·0	India-rubber	1·37
Zinc	225·0	Brick dust, fine	1·33
Lead	113·0	Coke dust	1·29
Marble, fine-grained	28·0	Cork	1·15
„ coarse-grained	22·4	Chalk, powdered	0·869
Stone, fine	16·7	Straw, chopped	0·563
„ ordinary	13·68	Coal dust	0·547
Glass	6·6	Wood ashes	0·531
Bricks	4·83	Sawdust, mahogany	0·523
Plaster	3·86	Canvas, new	0·418
Oak, across the grain	1·70	Calico, new	0·402
Walnut „	0·83	White writing paper	0·346
Fir „	0·748	Cotton wool or sheep's wool, any density	0·323
Fir with the grain	1·37	Eider down	0·314
Walnut „	1·40		

RESISTANCE OF CONDUCTIVITY.

Felt	1·000	Gas-house carbon	0·570
Silicate cotton	0·832	Asbestos	0·363
Sawdust	0·686	Coal ashes	0·343
Pine wood	0·553		

TESTS OF VARIOUS PIPE COVERINGS, MADE AT SIBLEY COLLEGE, CORNELL UNIVERSITY. *By Professor R. C. Carpenter.*

Kind of Covering.	Relative amount of heat transmitted.
Naked pipe	100·0
Two layers asbestos paper, 1 inch hair felt and canvas cover	15·2
„ „ 1 inch hair felt, canvas cover, wrapped with manilla paper	15·0
„ „ 1 inch hair felt	17·0

TABLE IX.—*continued.*

Kind of Covering.	Relative Amount of Heat transmitted.
Hair felt sectional covering, asbestos lined	18·6
One thickness asbestos board	59·4
Four thicknesses asbestos paper	50·3
Two layers asbestos paper	77·7
Wool felt, asbestos lined	23·1
„ with air spaces, asbestos lined	19·7
„ plaster of Paris lined	25·9
Asbestos moulded, mixed with plaster of Paris	31·8
„ felted, pure long fibre	20·1
„ and sponge	18·8
„ and wool felt	20·8
Magnesia, moulded, applied as a plaster	22·4
„ sectional	18·8
Silicate cotton (slag wool) sectional	19·3
Rock wool, fibrous	20·3
„ felted	20·9
Fossil meal, ¾-inch thick	29·7
Pipe painted with black asphalt	105·5
„ „ light drab lead paint	108·7
Glossy white paint	95·0

Much information is afforded by this series of tests. It shows conclusively that although we have distinctly good and bad conductors of heat, their efficacy in these respects depends very greatly on conditions. Materials applied loosely act as barriers of heat much better than the same substances tightly bound on. Hair felt, which the writer considers the most successful material in conserving heat, owes much to its being made up in a semi-loose state, much as nature puts the hair on the skins of animals. The felt consists more of air interstices than it does of hair, and were it ground up and plastered on the heated surface its effectiveness could not fail to be largely diminished.

These tests also show what has been referred to in this book when treating of the efficacy of hot water and steam radiators, that paint has practically no effect in spoiling the heat-distributing power of the iron, but in some cases actually improves it. It may be considered that paints, into the composition of which lead enters, can be safely used on radiating surfaces, irrespective of the colour required.

TABLE X.—CORRESPONDING DEGREES OF THE CENTIGRADE AND FAHRENHEIT THERMOMETERS.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
+ 220 =	+ 428·0	+ 96 =	+ 204·8	+ 69 =	+ 156·2
215 =	419·0	95 =	203·0	68 =	154·4
210 =	410·0	94 =	201·2	67 =	152·6
205 =	401·0	93 =	199·4	66 =	150·8
200 =	392·0	92 =	197·6	65 =	149·0
195 =	383·0	91 =	195·8	64 =	147·2
190 =	374·0	90 =	194·0	63 =	145·4
185 =	365·0	89 =	192·2	62 =	143·6
180 =	356·0	88 =	190·4	61 =	141·8
175 =	347·0	87 =	188·6	60 =	140·0
170 =	338·0	86 =	186·8	59 =	138·2
165 =	329·0	85 =	185·0	58 =	136·4
160 =	320·0	84 =	183·2	57 =	134·6
155 =	311·0	83 =	181·4	56 =	132·8
150 =	302·0	82 =	179·6	55 =	131·0
145 =	293·0	81 =	177·8	54 =	129·2
140 =	284·0	80 =	176·0	53 =	127·4
135 =	275·0	79 =	174·2	52 =	125·6
130 =	266·0	78 =	172·4	51 =	123·8
125 =	257·0	77 =	170·6	50 =	122·0
120 =	248·0	76 =	168·8	49 =	120·2
115 =	239·0	75 =	167·0	48 =	118·4
110 =	230·0	74 =	165·2	47 =	116·6
100 =	212·0	73 =	163·4	46 =	114·8
99 =	210·2	72 =	161·6	45 =	113·0
98 =	208·4	71 =	159·8	44 =	111·2
97 =	206·6	70 =	158·0	43 =	109·4

TABLE X.—*continued.*

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
+ 42 =	+ 107·6	+ 14 =	+ 57·2	− 14 =	+ 6·8
41 =	105·8	13 =	55·4	15 =	5·0
40 =	104·0	12 =	53·6	16 =	3·2
39 =	102·2	11 =	51·8	17 =	1·4
38 =	120·4	10 =	50·0	18 =	− 0·4
37 =	98·6	9 =	48·2	19 =	2·2
36 =	96·8	8 =	46·4	20 =	4·0
35 =	95·0	7 =	44·6	21 =	5·8
34 =	93·2	6 =	42·8	22 =	7·6
33 =	91·4	5 =	41·0	23 =	9·4
32 =	89·6	4 =	39·2	24 =	11·2
31 =	87·8	3 =	37·4	25 =	13·0
30 =	86·0	2 =	35·6	26 =	14·8
29 =	84·2	1 =	33·8	27 =	16·6
28 =	82·4	0 =	32·0	28 =	18·4
27 =	80·6	− 1 =	30·2	29 =	20·2
26 =	78·8	2 =	28·4	30 =	22·0
25 =	77·0	3 =	26·6	31 =	23·8
24 =	75·2	4 =	24·8	32 =	25·6
23 =	73·4	5 =	23·0	33 =	27·4
22 =	71·6	6 =	21·2	34 =	29·2
21 =	69·8	7 =	19·4	35 =	31·0
20 =	68·0	8 =	17·6	36 =	32·8
19 =	66·2	9 =	15·8	37 =	34·6
18 =	64·4	10 =	14·0	38 =	36·4
17 =	62·6	11 =	12·2	39 =	38·2
16 =	60·8	12 =	10·4	40 =	40·0
15 =	59·0	13 =	8·6		

TABLE X.—*continued.*

The following rule can be adopted for converting one thermometric scale into another:—

Cent. degrees ÷ 5 × 9 + 32 = Fahr. degrees.
„ „ ÷ 5 × 4 = Réaumur „
Fahr. „ − 32 ÷ 9 × 5 = Cent. „
„ „ − 32 ÷ 9 × 4 = Réaumur „
Réaumur „ ÷ 4 × 9 + 32 = Fahr. „
„ „ ÷ 4 × 5 = Cent. „

TABLE XI.

EQUIVALENT VALUE OF UNITS IN ENGLISH AND METRICAL MEASUREMENTS.

One foot = 12 inches = 30·48 centimetres = 0·3048 metre.
One metre = 100 centimetres = 3·2808 feet = 1·0936 yard.
One mile = 5280 feet = 1760 yards = 1609·3 metres.
One square foot = 144 square inches = $\frac{1}{9}$th square yard = 929 square centimetres = ·0929 square metre.
One square metre = 10,000 square centimetres = 1·1960 square yards = 10·764 square feet.
One cubic foot = 1728 cubic inches = 2832 cubic centimetres = 0·02832 cubic metres.
One cubic metre = 35·314 cubic feet = 1·3079 cubic yard.
One pound = 16 ounces = 453·59 grams = 0·45359 kilogram.
One kilogram = 1000 grams = 2·2046 pounds = 35·27 ounces.

FOR CONVERSION OF METRICAL TO ENGLISH MEASUREMENT.

Millimetres × ·03937 = inches.
„ ÷ 25·4 = „
Centimetres × ·3937 = „
„ ÷ 2·54 = „
Metre = 39·37 inches.
Metres × 3·281 = feet.
„ × 1·094 = yards.
Kilometres × ·621 = miles.
„ ÷ 1·6093 = „
„ × 3280·7 = feet.
Square millimetres × ·0155 = square inches.

TABLE XI.—*continued.*

Square millimetres ÷ 645·1 = square inches
„ centimetres × ·155 = „
„ „ ÷ 6·451 = „
„ metres × 10·764 = square feet.
„ kilometres × 247·1 = acres.
Hectares × 2·471 = „
Cubic centimetres ÷ 16·383 = cubic inches.

TABLE XII.

THE EXPANSION OF WROUGHT IRON PIPES BY STEAM HEAT.

Temperature of the Air when Pipe is fitted.	Length of Pipe when Fitted.	Length of Pipe when heated to		
		215°	265°	297°
		ft. in.	ft. in.	ft. in.
Zero	100 feet	100 1·52	100 2·12	100 2·31
32°	100 feet	100 1·47	100 1·78	100 2·12
64°	100 feet	100 1·21	100 1·61	100 1·87

TABLE XIII.—AREA AND CIRCUMFERENCE OF CIRCLES (THE INTERIORS OF STEAM AND OTHER PIPES).

Diameter.	Area.	Circumference.	Diameter.	Area.	Circumference.
inches.	inches.	inches.	inches.	inches.	inches.
$\frac{1}{8}$	0·0123	·3927	$\frac{3}{4}$	0·4418	2·356
$\frac{1}{4}$	0·0491	·7854	$\frac{7}{8}$	0·6013	2·748
$\frac{3}{8}$	0·1104	1·178	1	0·7854	3·141
$\frac{1}{2}$	0·1963	1·570	$1\frac{1}{8}$	0·9940	3·534
$\frac{5}{8}$	0·3068	1·963	$1\frac{1}{4}$	1·227	3·927

TABLE XIII.—*continued.*

Diameter.	Area.	Circumference.	Diameter.	Area.	Circumference.
inches.	inches.	inches.	inches.	inches.	inches.
1⅜	1·484	4·319	3¾	11·044	11·78
1½	1·767	4·712	4	12·566	12·56
1⅝	2·073	5·105	4½	15·904	14·13
1¾	2·405	5·497	5	19·635	15·70
1⅞	2·761	5·890	5½	23·758	17·27
2	3·141	6·283	6	28·274	18·84
2¼	3·976	7·068	6½	33·183	20·42
2½	4·908	7·854	7	38·484	21·99
2¾	5·939	8·639	7½	44·178	23·56
3	7·068	9·424	8	50·265	25·13
3¼	8·295	10·21	8½	56·745	26·70
3½	9·621	10·99	9	63·617	28·27

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